

# Permian Brachiopods of West Texas, II

G. ARTHUR COOPER

and

RICHARD E. GRANT

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# Permian Brachiopods of West Texas, II

*G. Arthur Cooper  
and Richard E. Grant*



SMITHSONIAN INSTITUTION PRESS

City of Washington

1974

## ABSTRACT

Cooper, G. Arthur, and Richard E. Grant. Permian Brachiopods of West Texas, II. *Smithsonian Contributions to Paleobiology*, number 15, pages 233-793, figure 40, plates 24-191, 1974.—The second of a six-part monograph on brachiopods from the reference area for the North American Permian in mountain ranges of West Texas and adjacent New Mexico, this volume presents a historical resumé of the ordinal classification of the Brachiopoda, definitions of morphological terms, techniques of measuring specimens, and remarks on the naming of species. The major part of the work consists of descriptions and illustrations of genera and species in the inarticulate superfamilies Discinacea and Craniacea and the articulate superfamilies Eichwaldiacea, Orthotetacea, Derbyiacea, and Lyttoniacea.

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Permian Brachiopods of West Texas, I. *Smithsonian Contributions to Paleobiology*, number 14, 231 pages, 39 figures, 23 plates, issued 29 December 1972.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year*. SI PRESS NUMBER 4787. SERIES COVER DESIGN: The trilobite *Phacops rana* Green.

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### Library of Congress Cataloging in Publication Data

Cooper, Gustav Arthur, 1902—

Permian brachiopods of West Texas.

(Smithsonian contributions to paleobiology, no. 14-15)

Includes bibliographies.

1. Brachiopoda, Fossil. 2. Paleontology—Permian. 3. Paleontology—Texas. I. Grant, Richard E., joint author. II. Title. III. Series: Smithsonian Institution. Smithsonian contributions to paleobiology, no. 14-15.

QE701.S56 no. 14, etc. [QE796] 560'.8s [564'.8'097649] 72-4218

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# Permian Brachiopods of West Texas, II

*G. Arthur Cooper and Richard E. Grant*

## Systematics

### HISTORICAL

Considering the richness of the fossil-bearing Permian rocks of Texas, it is surprising that so little work has been done in the past to make their faunas known. Most of the effort placed on the Permian of West Texas has been stratigraphic to satisfy the needs of exploration for oil. The first important fossil study is that of B. F. Shumard (1858, 1859), who described the specimens collected by his brother G. G. Shumard on an expedition under the direction of Captain John Pope to find artesian water in the arid southwest. Shumard recognized these specimens as Permian and helped to establish the presence of rocks of this age in North America.

Nothing more was done in the description of brachiopods of this part of Texas until the collections that were made by R. T. Hill, G. B. Richardson, and G. H. Girty from various parts of West Texas, including the Glass and Guadalupe Mountains, were described in the now famous "Guadalupean Fauna" of Girty (1909). This monograph finally fixed the Permian age of these fossils beyond debate. Girty continued this work in 1929 by describing some fossils from the Hueco Group.

The Glass Mountains fauna was described by R. E. King (1931), who described 185 species. Most of them were compared with those of Girty and Shumard but many new ones were included. This

work was a great step forward and the faunal summary contained in it is still valuable. The next work containing information on brachiopods is that of P. B. King (1948), the "Geology of the Southern Guadalupe Mountains, Texas." This contains extensive and valuable notes on the brachiopods by Girty. Following this, the study "Permian Reef Complex of the Guadalupe Mountains Region, West Texas and New Mexico" by N. D. Newell and party (1953) was issued. This work contains an extensive compilation of brachiopods and one plate illustrating some of the important species occurring in that area, but it makes no new contribution to knowledge of the brachiopods except for some details of their stratigraphy.

Walter (1953) described a fauna from the Rustler Formation of West Texas, which is the youngest known Permian fauna in the area. Stehli (1954) published an account of the "Lower Leonardian Brachiopoda of the Sierra Diablo," describing new genera and species and adding materially to knowledge of Permian fossils. In shorter papers in 1955 and 1956, Stehli described interesting rhynchonellids and oldhaminidinids from West Texas, chiefly from the Delaware Basin but also from the Guadalupe Mountains. Cooper and Stehli (1955) described some new genera and species from the Glass Mountains.

Muir-Wood and Cooper (1960), in their discussion of the Productidina, described a number of new genera and species from the Glass Mountains. Grant (1965) described some of the Stenosclerataceans from West Texas in a comprehensive study of that group of brachiopods. In the same year P. B. King (1965) published the "Geology of the

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Sierra Diablo Region, Texas," which includes extensive lists of brachiopods prepared by P. E. Cloud. These monographs and smaller papers all proved most helpful, but they cover only a small part of the faunas ultimately collected by the present authors. Termier, Termier, and Pajaud (1967) described a new genus from the Glass Mountains thought to be the root stock of the Thecideidina. Cooper and Grant (1969) published 34 new genera from West Texas as a preliminary note to the present monograph.

#### GENERAL DISCUSSION

The variety and perfection of the fossils described herein attest to the value of searching for silicified specimens. Most of the genera can be illustrated completely with good interior as well as exterior details. The specimens thus contribute importantly to the systematics of the Brachio-poda. The major classification depends largely upon family characters, chiefly those of the dorsal interior. Generic characters are found among details of the exterior and some features of the pedicle valve interior. The practice is best exemplified in the classification of the revived superfamily Orthotetacea. This is divided into two major groups based on the character of the cardinalia whether with or without supporting plates. The genera are based on aberrations of the pedicle valve interior, i.e., on the presence or absence of dental plates, on the character of the dental plates, and also on the strength of the cardinalia. *Geyerella* and *Ombonia* have similar ventral valve interiors, but the cardinal process of the former is large and ponderous, that of the latter short and delicate. They also have different shapes, that of *Geyerella* suggesting origin from *Meekella* but the other indicating possible derivation from *Derbyia*.

We also continue to classify all of the punctate genera as a related line. This is contrary to present thought, which argues for the polyphyletic origin of punctae. It is our belief that punctae originated from an impunctate stock, but, once developed, lines parallel to those of impunctate stocks evolved. The brachiopod, being a fairly primitive sessile animal, did not have many lines of evolution available; consequently, much repetition of form took place among the various developing punctate and impunctate lines. It is difficult to follow the

argument that the terebratulids were derived from impunctate spirifers because the initial loop and spire have the same form. The spire scarcely could have had any other form in such minute shells. It seems more reasonable to derive the terebratulids from the punctate dalmanellids rather than from any impunctate stock. The homeomorphy of the punctate brachiopods seldom converged toward developments of the pseudopunctate line.

#### GENERAL REMARKS ON THE PERMIAN FAUNA

The Permian fauna is one of the most interesting in the geological column because it contains culminating stocks that disappear at the end of Paleozoic time. It also contains the transient stocks that survived the Permian and gave rise to the Triassic and later Mesozoic faunas. Unfortunately the Glass Mountains and Guadalupe Mountains do not contain very late Permian faunas. It is impossible, therefore, to describe the culminating forms accurately, although it is possible to detect in some of the major groups elements that foreshadow the Triassic.

#### INARTICULATA

Only one genus of chitinous inarticulates, *Roemerella*, was found in all of the collecting. This may be explained in two ways: the facies is wrong and the method of collecting is not conducive to preservation of the chitinous genera. No lingulids were seen in any of the sediments. Normally these would not be expected in the coarse lime sands of most of the formations. But lingulids were not seen in any of the dark mud rocks either, where they would be expected. This might be because of possible deep water deposition of the mud rocks (since lingulids are commonly shallow water animals). It is also possible that dissolution of blocks in hydrochloric acid dissolved or destroyed any specimens that might have been present. The one specimen of inarticulate recovered from acid was seen by accident and split out before it had been completely destroyed. It is unusual for its large size.

The few inarticulates occurring in abundance are the cranias, which are difficult to recognize in piles of debris and which are represented by brachial valves only. Although we have searched carefully,

no pedicle valves were seen on corals or other brachiopods. One would think that the broad surfaces of the ventral side of the lyttoniids would be ideal places of attachment for *Crania*, but no specimens were seen there. The Permian was evidently a poor time for the inarticulates because few of them are recorded in faunas from other parts of the world. Branson (1948) lists only six genera.

#### ARTICULATA

One great value of the Glass Mountains silicified specimens is their reefy forms, often preserved in growth position and with interior characters in perfection. Important among these are the Orthotetacea, which have been the subject of such speculation as to how they lived.

ORTHOTETACEA.—Perhaps the heyday of the Orthotetacea was in the Wolfcampian, when many bioherms were composed substantially of their shells. A greater variety of these brachiopods appears in that time than any other. Then the schuchertellids were diverse but on the wane, and *Derbyia*, living on from the preceding period, flourished in a variety of forms. *Meekella*, inherited from the Pennsylvanian, became one of the commonest brachiopods, and gigantic forms are preserved in the Decie Ranch Member. They were matched in size, but not abundance, by their external homeomorph, *Geyerella*. The Orthotetacea started to fall off in numbers and kinds after the Wolfcamp (as defined herein). *Geyerella* and *Derbyia* lingered into the upper Bell Canyon but were rare. The Guadalupian is characterized more particularly by *Ombonia*, but this genus is not widely distributed in the United States. The Capitan reef faunas have few specimens of Orthotetacea other than *Ombonia*. One large *Derbyia*, known from poor scraps, and *Meekella* occur with a small *Tropidelasma*. In Asia a few other genera such as *Orthothetina* occur, but the superfamily was on its way out in the Late Permian.

OLDHAMINIDINA.—From humble beginnings in the Pennsylvanian, this group blossoms into importance in the Wolfcamp. The earliest form, *Poikilosakos*, inherited from the Pennsylvanian, is rare in the Permian, but its successor, *Pseudoleptodus*, becomes fairly common and extends into the Capitan and Bell Canyon formations. Large forms occur in the late Word. Other related genera such

as *Sceletonia* and *Choanodus* are rare. *Eolyttonia*, primitive but variable and the commonest form in the Lower Permian, produced gigantic conical species in the late Wolfcampian. It is displaced in the late Leonard and Word by *Collemataria*, which contributed importantly to bioherms in the Cathedral Mountain Formation but lived in small clusters in the Word. This genus persisted into the Capitan and Bell Canyon formations but never attained the abundance of earlier times; it is relatively rare in the late Guadalupian. The evolution of this group was directed to compressing the lobes of the pedicle valve into septa and to elimination of the conical form of the early genera, whereas the evolution of the exterior of *Poikilosakos* was directed toward the development of a conical form and elevation above its host. Its interior however was largely static.

CHONETIDINA.—Although the chonetids of the Permian of West Texas are abundant in places and occur in swarms in some formations, they do not seem to have evolved conspicuously. The majority of forms, which are smooth, developed a widely extended outline in the late Leonardian and early Guadalupian. In the upper Word of the Glass Mountains, however, they tended to a more rectangular or quadrate form. In the Bell Canyon and Capitan formations they maintained their transverse outline, but generally they were smaller than those of the late Leonardian. The *Neochonetes* stock became extinct in the Wolfcamp, but costellate chonetids (*Rugaria*) of uncertain origin appeared late in that time—but did not persist.

PRODUCTIDINA.—The productids are legion in the Permian. They, more than any other brachiopod, are likely to be found in any of the facies. The Permian was also the time when the Strophalosiacea had their greatest development. The Productacea match those of the Mississippian (Viséan) in variety of form and adaptation and even exceed them in diversity.

The Aulostegacea now are separated as a superfamily distinct from the Strophalosiacea. They lack the teeth and sockets that are retained by the Strophalosiacea and, in addition, have developed high interareas for more advantageous attachment of the ventral beak to the substrate. The Strophalosiacea in the Glass and Guadalupe Mountains are represented mainly by small attached shells

that constitute important epifaunas in some parts of the column, especially in the Word. The Aulostegacea, on the other hand, are represented by large and robust forms that contribute importantly to bioherms. The earliest of these, *Limbella*, appears in the Pennsylvanian, but it becomes abundant in parts of the Wolfcamp. It probably gave rise to *Edriosteges*, an abundant element in the upper Cathedral Mountain and in the Road Canyon Formation. *Echinosteges* is characteristic of the Guadalupian, although it appears first in the Road Canyon Formation. A variety of small Aulostegacea such as *Xenosteges*, *Scapharina*, and *Cooperina* are important members of the epifauna that covers dead shells or the exterior of living ones in the Guadalupian. *Glyptosteges*, *Spyridiophora*, and *Institella* are highly sculptured shells, leptaenoid in form and seemingly unlikely as attached brachiopods, yet they are fixed by the beak and anchored by spines that often are very long, as in *Institella*. *Chonosteges* with its bizarre anterior funnels—probably intake valves for feeding—is the most highly specialized member of the superfamily. The Aulostegacea become rare above the Word.

Offshoots from the strophalosiid line, we believe, are *Teguliferina* and *Acritosia*, which contrast strongly with the richthofeniidae, which they resemble superficially in the absence of vesicular tissue in the apex of the pedicle valve, a strongly oblique cone, and a strophalosiid type of cardinal process. These appear in the Pennsylvanian, but they increase in size, numbers, and kinds in the Wolfcampian.

Although *Tschernyschewia*, an aberrant genus with a strong ventral median septum and forked cardinal process, obviously is related to *Scacchinella*, the two genera in Europe are widely separated in time. In the Glass Mountains, however, they are contemporaries. *Tschernyschewia* is an extremely rare shell, but it is known in the Skinner Ranch and Road Canyon formations.

*Scacchinella* differs from *Tschernyschewia* chiefly in the "reefy," strongly conical form of the pedicle valve and the growth habit of cementation and strengthening the hold by fastening with spines. *Scacchinella*, as a contemporary of *Tschernyschewia*, probably was not derived from it, but the two may have had the same, but now unknown,

source. *Scacchinella* was inherited from the Pennsylvanian when it was very rare, but it is abundant in the Skinner Ranch, less so in earlier formations and members.

The Productacea are numerous and important in the Permian. Thirty-seven genera appear in the Wolfcampian (*Uddenites*-bearing Shale Member), which includes representatives of major families except the Productellidae and Leioproductidae. With this good beginning, a wide deployment of genera and species resulted. The Overtoniidae are represented by only three small and rare genera. *Fimbrinia* does not survive the Wolfcampian, and *Rhytisia* and *Simplicarina* are confined to the Road Canyon Formation. The Marginiferidae are more abundantly represented and include three subfamilies. *Hystriculina* and *Kozlowskia*, holdovers from the Pennsylvanian, generally are rare and do not survive the Wolfcampian. Of the Costispiniferinae, *Echinauris* is the most abundant and attains a large size in the upper Word, but it does not extend higher. *Bothrionia*, which is similar to the preceding, is interesting for the development of an anterior tubulation like that of *Chonetella* from the Salt Range. *Kutorginella* and *Thamnosia* represent the third family (Retariinae); they evolved large species that also are characterized by the development of anterior tubes in the upper Word and Capitan formations.

The Echinoconchidae are represented abundantly in the Pennsylvanian, but not many flourished in the Permian. *Echinaria* and *Calliprotonia*, rare in the early Wolfcampian, did not survive into the Lenox Hills Formation. The same is true of *Juresania*, which is common in the late Pennsylvanian and early Permian of the Midwest. *Waagenoconcha* appears in the late Pennsylvanian (Cisco) and occurs sparsely in the Permian into the upper Word. Actually, there is some uncertainty about the generic affinities of the North American *Waagenoconcha*. *Kochiproductus* undoubtedly has a Pennsylvanian ancestor, but it extends well into the Permian. It is often represented by huge forms, especially in the Arctic Permian. Several large species occur in West Texas, but the genus becomes extinct at the end of the Leonardian.

The Dictyoclostidae are well represented in the Permian of West Texas by genera inherited from the Pennsylvanian and by new ones that evolved



later. *Dasysaria*, a strongly convex and finely reticulate genus, characterizes the Wolfcampian to which it is confined. *Reticulatia*, common in the Pennsylvanian, fails to survive the Wolfcampian. *Nudauris*, *Spinifrons*, and *Antiquatonia* are uncommon and mainly Wolfcampian types. *Peniculauris* is a large dictyoclostid that takes over the place of *Reticulatia* in the fauna and is characteristic of the Skinner Ranch Formation through the Road Canyon, after which it is unknown. *Rugatia* marks the upper Cathedral Mountain and Road Canyon formations, while *Xestosia* and *Spinarella* belong in the Cathedral Mountain and Road Canyon formations respectively. In West Texas the family disappears at the end of the Road Canyon Formation. *Horridonia*, best known in the Arctic, is a rare element in that formation.

The Linoproductidae are represented by a variety of unusual forms. *Linoproductus* and *Cancrinella* are inherited from the Pennsylvanian, but generally they are rare forms that persist to the top of the Word. *Cancrinella* may have given rise to two bizarre Late Wolfcampian forms: *Liraria* and *Undellaria*. These are very rare, with very thin and fragile shells. *Grandaurispina* is another relative of *Cancrinella* that began in the Cathedral Mountain Formation but extends to the end of the Word. *Megousia* is one of the commonest of West Texas linoproductids, originating high in the Skinner Ranch and extending into the Capitan, where it is very rare. *Holotricharina* is unusual in having two kinds of spines on its pedicle valve. *Siphonosisia*, from the lower Cathedral Mountain, is unusual for its convergence toward *Proboscidea* of the Old World Viséan.

The subfamily Striatiferinae is represented abundantly in all reefy parts of the section and in a few others as well. We have called one species in the lower Neal Ranch *Striatifera* because it has a narrow but well-formed hinge and is quite unlike *Compressoproductus*, which is acuminate and without a straight hinge.

Paucispiniferidae are among the commonest of the West Texas productids. *Liosotella* and *Paucispinifera* abound from the Road Canyon to the top of the Word. They also appear in the Bell Canyon and Capitan formations, where they are the most frequent productids. *Anemonaria*, from the lower Cathedral Mountain, is possibly the pro-

genitor of the line. *Polymorpharia* is a Word aberration of *Paucispinifera*, having a bizarre form, possibly the result of attachment.

The Richthofeniaceae, among the most typical of Permian fossils, were abundant in the Leonardian. They probably originated in the Pennsylvanian or early Permian. Two stocks can be distinguished, one with a strong median septum, the other without a septum. The stocks show parallel development from an aperture protected by spines to one with a coscinidium. The latter group developed a form, *Collumatus*, with a coscinidium but without anchor spines. In late Guadalupe time two genera lived simultaneously, one with a coscinidium, the other without one, but neither genus was common at that time.

**RHYNCHONELLIDA.**—The rhynchonellids are everywhere and in great variety. They are remarkable in having a completely smooth sulcate genus, *Paranorella*, and a number of fine-lined forms such as *Lirellaria*, and *Ptilotorhynchus*. The latter genus, with its winged deltidial plates, suggests some genera of the Mesozoic. The crura of many of the genera are similar to modern forms as they have typical falcifer crura. Development of an apical chamber or "septalium" is rare in these rhynchonellids. The median septum is evanescent; about as many genera lack the septum as possess it. Nevertheless, its presence or absence seems a valid means of distinction. A number of genera such as *Deltarina*, *Fascicosta*, and *Divaricosta* have divided or intercalated costae, a rare condition among rhynchonellids. *Leiorhynchoidea scelestia* is a huge form for a Paleozoic rhynchonellid. A modern trend in the Glass Mountains rhynchonellids is the tendency toward smoothness or the development of fine lines on the exterior. *Amphipella*, with its interior pouches, is a remarkable development and a smooth rhynchonellid as well.

**SPIRIFERIDINA.**—Except for the discovery of the buccal plate in *Neospirifer*, this group shows little evolution or advance over its predecessors. Aberrations of form and ornament made possible the recognition of *Gypsospirifer*, *Lepidospirifer*, and *Cartorhium*. The first genus characterized the early Wolfcampian, while the second is diagnostic of the Cathedral Mountain and upper Skinner Ranch. The last extends from the Cathedral Mountain into the Capitan. *Spiriferella* is first seen in

the Road Canyon Formation, where it is very rare. It is common throughout the Word but rare again in the Bell Canyon, where it is represented by a small species. *Eridmatus* is inherited from the Pennsylvanian, but it does not survive beyond the *Uddenites*-bearing Shale Member. *Eliva* and *Elivina* are confined to the Bell Canyon and Capitan formations. *Spiriferinaella* is a rare wide-hinged spiriferid hitherto improperly classified with the Spiriferinidae, which appears in the Road Canyon and extends to the upper Word.

*Composita* is legion, but no general trend of evolution was detected. Two developments toward gigantism appear, one toward the end of the Word and the other in the Capitan. *Rallacosta* and *Heteraria* are new types appearing in the Cathedral Mountain and Bell Canyon formations. *Astegosia* and *Anomaloria*, contemporaneous homeomorphs, are common only in the upper Capitan Formation and the Lamar Member. *Neophricadothyris* is common in Wolfcamp and Leonard rocks but rare in the Word. One of the surprises is discovery of *Nucleospira* in the Permian, a genus hitherto known to range from middle Silurian to the lower middle Mississippian. *Xenosaria* is a new genus, having the external form of *Nucleospira* but with different cardinalia. *Crurithyris* occurs in all of the formations, but *Cleiothyridina*, which is abundant in the Eurasian Permian, is very rare in the West Texas sequence. It is an inheritance from the Pennsylvanian, but it did not flourish in the West Texas Permian. Its species range from tiny to small.

**RHIPIDOMELLIDA.**—The punctate rhipidomellids occurring in the Permian are the final expression of a line that originated in the early Ordovician. The Permian *Rhipidomellae* are like the Pennsylvanian ones in having a narrow hinge and small interarea, and they suggest *Perditocardinia*. In a few places in the Glass Mountains and Sierra Diablo, *Rhipidomella* is abundant in the lower strata, but it does not survive into the Road Canyon Formation.

Four genera of Enteletacea occur in the Glass Mountains. The small *Acosarina* ranges from the Neal Ranch Formation through the Road Canyon, but the larger *Orthotichia* is characteristic of the Wolfcamp only. *Enteleles* is common in the Wolfcamp, in places abundant in the Cathedral Moun-

tain and Road Canyon, and extends to the lower part of the Willis Ranch Member of the Word, above which it disappears. An offshoot of *Enteleles*, the sulcate genus *Parenteleles* is nowhere common. It is inherited from the Pennsylvanian and extends into the Lenox Hills Formation, where it is rare. A single occurrence is known in the Skinner Ranch Formation (Poplar Tank Member). No evolutionary trends were detected in the enteletids except for the development of huge *Enteleles* in the Taylor Ranch Member of the Hess Formation and in the lower part of the Word, after which the genus disappears in the United States.

**RHYNCHOPORACEA.**—*Rhynchopora* is inherited from the Pennsylvanian and is a rare shell. It occurs in the Wolfcamp and extends to the top Word in the Glass Mountains. It was not seen in the Bell Canyon or Capitan formations in the Guadalupe Mountains.

**SPIRIFERINACEA.**—Several new genera have been recognized in the Spiriferinacea, which are fairly common in the Glass Mountains but are abundant in the Bell Canyon Formation. *Reticulariina* is inherited from the Pennsylvanian, but *Punctospirifer*, widely identified in Pennsylvanian rocks, does not appear in the Permian of West Texas. It appears in the Wolfcampian shale sequence in north-central Texas but not in the limestone sections. *Crenispirifer*, *Spiriferellina*, *Paraspiriferina*, *Altiplecus*, and *Reticulariina* are long ranging and appear in all parts of the column. *Sarganostega* is confined to the Bell Canyon and Capitan. *Metriolepis* is seen first in the Skinner Ranch Formation, but it extends to the Lamar Member of the Bell Canyon Formation. One member of this genus exhibits a new type of deltidial cover. *Arionthia* is rare.

*Hustedia* and *Thedusia* are narrow-hinged punctate spiriferids that are very abundant in all parts of the column. A tendency to gigantism appears in the Skinner Ranch and Bone Spring formations in *H. hessensis*, in the Word Formation with *H. pugilla* and its varieties, and in the Bell Canyon with *H. rupinata*. An interesting species appears in the genus *Thedusia*, in which both valves are slit from the anterior nearly to midvalve to fore-shadow the lobation of *Pygope*.

**TEREBRATULIDA.**—*Dielasma* and *Beecheria* are inherited from the Pennsylvanian, the former to

exist throughout the range of the rocks treated herein, but the latter not surviving the Wolfcampian. *Lowenstamia* and *Camarelasma* are small forms restricted to the Wolfcampian, and *Aneuthelasma* is an amygdaloidal genus confined to the Bell Canyon Formation. *Plectelasma* is characterized by an anteriorly plicated front margin. It is rare in the Skinner Ranch Formation and the Appel Ranch Member of the Word, fairly common in the Bell Canyon Formation, but rare in the Capitan. *Ectoposia* has a loop suggesting those of the short-looped terebratulids of the Jurassic.

*Pseudodielasma* and its rare plicated offshoot *Pleurelasma* are characteristic of the Word and Bell Canyon formations. The former genus occurs in swarms in the Willis Ranch Member of the Word Formation, but *Pleurelasma* is very rare.

Terebratulids with a centronelliform loop—*Chondronia*, *Notothyris*, and *Timorina*—are small and generally very rare.

The long-looped brachiopods such as *Heterelasma*, *Cryptacanthia*, *Glossothyropsis*, and *Texarina* are rare, but each of these genera has been discovered in sufficient abundance to illustrate the full development of their loops. This is a significant contribution to knowledge of the Terebratulida.

#### TERMINOLOGY

The terminology used in this monograph, unless specifically defined under special groups such as the Oldhaminida and Orthotetacea, is that proposed by J. Allan Thomson (1927) and Schuchert and Cooper (1932). We have used "pedicle and brachial valve" to denote the two shells because most of the manuscript was prepared when there was uncertainty as to the orientation of the shell. In general our terminology is in accord with that proposed in the "Treatise" (1965) with the exception of the term "socket ridge." Our view on this is explained in detail in the discussion of the Spiriferida.

#### MEASUREMENT OF THE SPECIMENS

A note on the measurement of specimens illustrating the species is important. The many measurements are not entirely precise because the specimens were too fragile to bear the pressure of

calipers. Some specimens were lost by breakage in the attempt to measure them. Some measurements could not be taken but had to be approximated because of abundant spines or spine bases on the surface. This was especially true of the longitudinal surface measure of many of the productids, in which numerous spines were well preserved.

An asterisk (\*) after a measurement indicates that the figure given is based on a half measurement, that is, the width, hinge, or other lateral measurement is based on the more complete or well-preserved half of a specimen; the final figure, thus, would be double the actual measurement. This of course may not be the true measure of a particular dimension because most specimens are never exactly bisymmetrical.

#### NOTE ON THE NAMING OF SPECIES

This monograph contains a large number of specimens that are described and illustrated without receiving formal names. To the casual reader this may suggest inconsistency since we have named formally some species that are based on a few specimens or only a single specimen. The explanation is that some specimens are so distinctive that their usefulness as a species is not jeopardized by their rarity. A seemingly abnormal single specimen would not be named in any case. The appellation "species" has been used on some suites of specimens, often including a supply that might be considered sufficient to name a species. We have refrained from naming some of these lots because the specimens have indefinite or generalized characters that make differentiation from other species difficult. An example is *Grandaurispina* from locality USNM 721u. This is the oldest species of the genus, but the five specimens in the lot do not crystallize the concept of the species. We believe it important that such material, having a critical meaning as the herald of a stock, an aberrant occurrence, or a stratigraphic anomaly, should be described and illustrated even though not named. Every bit of evidence that can be brought to bear on the biology and stratigraphy of these fossils should be presented.

#### ABBREVIATIONS

Abbreviations (used with catalog numbers),

showing ownership of the specimens illustrated or mentioned in the systematic part of this monograph, are as follows:

AMNH=American Museum of Natural History

USNM=United States National Museum (collections in the National Museum of Natural History, Smithsonian Institution)

UT=University of Texas (Bureau of Economic Geology)

YPM=Yale Peabody Museum

USNM locality numbers for the Permian of West Texas are in a 700 series. When cited in descriptions, they will carry only the abbreviation "USNM" except when they appear with the above catalog numbers, in which case, both the terms "locality" and "type" will be used, where necessary, with the abbreviations to avoid confusion. For the abbreviation of other visitations or names used with locality numbers, see "Register of Localities" in volume I of this monograph.

## Class INARTICULATA Huxley, 1869

### Order ACROTRETIDA Kuhn, 1949

#### Suborder ACROTRETIDINA Kuhn, 1949

#### Superfamily DISCINACEA Gray, 1840

#### Family DISCINIDAE Gray, 1840

#### Subfamily ORBICULOIDEINAE Schuchert and Levene, 1929

The few specimens described below are the only representatives of the hingeless brachiopods that have a chitinous shell. No linguloids were found in any part of the Permian of the Glass Mountains, Guadalupe Mountains, or Sierra Diablo. In some parts of the Paleozoic they are fairly common, but they are rare in this part of the Permian. Two reasons seem to explain this scarcity of chitinous brachiopods. The first is the fact that most of the residues on which this study is based were taken from rocks deposited in turbulent near-shore environments, from conglomerates, and from coarse lime sands. The few fine-grained rocks in the sequence studied have not produced any of these shells, nor have the bituminous limestones, where they might be expected to appear, as in parts of the Road Canyon or Bell Canyon formations.

These bituminous limestones, also showing some evidence of turbulence, may not have been a hospitable environment for them.

Another possible reason for not finding any of the linguloids is that the hydrochloric acid used in dissolution dissolves or destroys chitinous or phosphatic materials; consequently, if rare specimens were present, they may have been lost.

In spite of these unfortunate circumstances, one startlingly large chitinous brachiopod was found by accident. In addition, the calcareous Inarticulata (Craniacea) are found now and then and have left an interesting record of their existence.

## Genus *Roemerella* Hall and Clarke, 1890

### *Roemerella gigantissima*, new species

PLATE 24: FIGURES 7, 8

Unusually large for genus, wider than long, shell narrowing in posterior direction; anterior margin rounded. Sides flattened or indented and narrowed just posterior to midvalve, more broadly rounded than posterior margin. Surface marked by narrowly rounded concentric undulations separated by rounded grooves of slightly greater width, and numbering about 4 in 5 mm near margin.

Pedicle valve of variable convexity, posterior part nearly flat but anterior part moderately concave. Pedicle opening small, elliptical, and located just posterior to apex, which forms most concave part.

Brachial valve poorly preserved but forming a low cone with apex probably somewhat eccentric.

MEASUREMENTS (in mm).—Holotype (pedicle valve): length about 61, maximum width (half measure) 65, length of pedicle opening 10; paratype (brachial valve): length 68.5, maximum width 68.5, height 6.5?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation (top).

LOCALITY.—USNM 703.

DIAGNOSIS.—*Roemerella* of gigantic size.

TYPES.—Holotype: USNM 151393a; paratype: 151393b.

COMPARISON.—This is the largest species of the genus known and one of the largest orbiculoids yet described.

DISCUSSION.—Two specimens are in the collection, one representing each valve, but neither is well preserved. The brachial valve is badly



crushed and part of it was lost, but enough can be seen to establish that it was a low cone with the apex probably eccentric. This specimen also shows the flattening or emargination of the sides just posterior to midvalve, indicating a definite posterior narrowing of the shell to produce a more rounded posterior and broadly rounded anterior—a feature seen in both valves.

The pedicle valve is definitely flat to convex in the posterior half but concave in the anterior portion so that this part of the valve extends well into the cavity of the brachial valve. Details of the pedicle opening are too obscure to determine. It is small for a shell of such gigantic proportions.

#### Suborder CRANIIDINA Waagen, 1885

#### Superfamily CRANIACEA Menke, 1828

#### Family CRANIIDAE Menke, 1828

These scalelike brachiopods generally have been overlooked in the American Permian. Branson (1948) reports only two species of *Crania* and the dubious craniid *Choniopora*. We have seen several craniids outside of the Glass Mountains, one occurring in the early Permian of Kansas and another, from Australia, attached to the large auslostegid *Taeniothaerus*. The residues from numerous localities in West Texas have yielded a variety of craniids but none in abundance. The variety recovered from the residues suggests that they were widespread and probably common but that they have been overlooked in ordinary collecting methods.

The craniids are difficult to detect in the residues because some of them have no definite form. Some of the platyceratid snails may be confused with them. Fortunately examination of the concave side of these scalelike objects usually reveals the nearly central and marginal large muscles that separate them from the cap-shaped snails. In some the preservation has been so good that punctae are readily visible and contain evidence that the shell is a brachiopod.

In all of the enormous amount of siliceous residues examined in the course of this study we found only two craniids attached to their hosts. We have not found a single pedicle valve, consequently all of the species made herein are based on brachial

valves only. We have carefully searched the surfaces of all corals, sponges, bryozoans, and any other massive shells or objects recovered for these elusive valves. It is odd that attached *Poikilosakos* and numerous juvenile leptodids, richthofeniids, and productids have been found, but craniid pedicle valves failed to appear. The number of brachial valves found is no smaller than that of other attached forms that shed one valve on death.

The remarkable feature of the Permian craniids from West Texas is the predominance of ornamented shells. *Acanthocrania*, adorned by a mat of fine spines, is the most abundant genus. The new lamellose genus *Lepidocrania* is the next most abundant genus, and the remaining two are very rare.

Species of Craniidae are difficult to distinguish, as in all attached brachiopods. Chief reliance is placed on the ornament in the spiny and lamellose forms. Another complicating factor in the recognition of species is the fact that the ornament of the host often is faithfully preserved on the exterior of the brachial valve as it grows over the surface of the host. The collection of Craniidae described herein is actually not large, but it represents a considerable span of the Permian and indicates wide diversity in these peculiar forms. It is anticipated that each new discovery of specimens will tend to modify understanding of those described. It is also anticipated that further discovery will lead to a proliferation of species and possibly of genera.

Orientation for measurements of valve length from posterior to anterior depend upon a view of the inside, where the muscle marks can be seen on the posterior margin. Distortion of some shells could lead measurements awry, but reference to the muscles gives the correct orientation. The measure of surface length helps to depict the convexity of the shell, as it does in the productids. A flat shell and a steeply conical one may have the same length, but the surface measure will indicate the convexity.

#### Genus *Acanthocrania* J. S. Williams, 1943

*Acanthocrania* J. S. Williams, 1943:71.

This name was proposed for craniids having the exterior covered by fine spines. The genus appears to be abundant in the Ordovician (Cooper, 1956),

but it is not well known between that period and the Mississippian from which Williams took his type-species. It is poorly known in the Pennsylvanian, but the etch residues from the West Texas Permian has revealed it in numbers sufficient to lead to the belief that it was widely distributed and probably fairly abundant. The Permian specimens show no evolutionary advance over the early Paleozoic representatives. Evidently all of the craniids were very conservative.

*Acanthocrania alta*, new species

PLATE 27: FIGURES 2, 3

Medium size for genus, subquadrate in outline, high conical in profile. Posterior margin nearly straight; anterior margin gently convex; sides slightly curved; profile a misshapen cone with beak about one-third of length from margin; posterior slope long and precipitous; lateral slopes steep; anterior slope steep, but not so strongly inclined as others. Surface very irregular but covered with felt of long, slender spines.

Interior with large thick anterior adductor scars. Posterior scars smaller and marginal, widely separated.

MEASUREMENTS (in mm).—Holotype: length 6.7, width 7.0, surface length 11.0, height 4.0.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Base).

LOCALITY.—USNM 720g.

DIAGNOSIS.—Strongly conical *Acanthocrania*.

TYPES.—Holotype: USNM 152571.

COMPARISON.—This species is most similar to *A. densispina*, new species, although its spines are finer but not so fine as those of *A. minutispinosa*, new species. Its cone is differently proportioned, the posterior side is more abrupt and steeper, and the beak almost overhangs the posterior slope.

*Acanthocrania conferta*, new species

PLATE 27: FIGURES 22–26

Medium size for genus; wider than long and with subquadrangular outline; sides and anterior margin rounded; posterior margin usually straight. Profile conical, apex rounded and variable in position, usually one-fourth to one-third length from posterior margin; posterior slope short and steep; anterior

slope convex; lateral slopes moderately steep. Surface not lamellose but covered by dense mat of short, thin, stubby spines.

Brachial valve interior with small marginal adductor scars but large crowded adductor scars. Some specimens with small anteriorly located median ridge.

MEASUREMENTS (in mm).—

|                    | length | midwidth | surface length | height |
|--------------------|--------|----------|----------------|--------|
| AMNH 512           |        |          |                |        |
| 151429a            | 8.6    | 10.6     | 12.0           | 3.7    |
| 151429b            | 7.4    | 8.0      | 9.5            | 2.5    |
| USNM 732           |        |          |                |        |
| 151430a            | 6.7    | 6.3      | 7.5            | 3.0    |
| 151430b (holotype) | 6.2    | 7.2      | 8.0            | 2.7    |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (China Tank Member).

LOCALITIES.—Getaway: AMNH 512, USNM 730, 732; China Tank: USNM 706z.

DIAGNOSIS.—Nonlamellose *Acanthocrania* covered with a dense mat of small spines.

TYPES.—Holotype: USNM 151430b; figured paratype: 151429a; unfigured paratypes: 151429b, c; measured paratypes: 151429b, 151430a, b; unmeasured paratypes: 151430c–f.

COMPARISON.—This species, in the density of the spines on its surface, may be compared to *A. densispina* and *A. minutispinosa*, but the spines are stouter than in both of these and are shorter than those of *A. densispina*. It is difficult to use size or shape as specific characters in the craniaceans, but *A. conferta* appears to have a generally lower cone and larger shell. The species is rare, perhaps because of the difficulty in detecting such misshapen objects in piles of residue. As in the other species, we have not seen a pedicle valve.

*Acanthocrania densispina*, new species

PLATE 27: FIGURES 12–18

Medium size for genus, rounded quadrangular in outline with width slightly greater than length; posterior margin straight; sides and anterior margin rounded; profile conical, apex located about one-third length from posterior margin; posterior slope precipitous; anterior slope long and steep. Surface coarsely lamellose and covered by dense mat of short, delicate spines.

Brachial valve with adductor scars widely spaced and small; anterior adductor scars large, closely spaced. Marginal brim broad and well developed in old specimens, less so in young.

MEASUREMENTS (in mm).—

|           | length | midwidth | surface<br>length | height |
|-----------|--------|----------|-------------------|--------|
| USNM 702c |        |          |                   |        |
| 151434a   | 6.2    | 7.0      | 8.0               | 2.8    |
| 151434b   | 6.4    | 8.2      | 10.0              | 3.3    |
| 151434c   | 8.0    | 8.0      | 10.0              | 4.7    |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 702, 726x; Road Canyon: 702c, 703a, 719x, 720d, 721j, 721z, 722e, 724c, 724j.

DIAGNOSIS.—Fairly high lamellose cones with a dense mat of small spines.

TYPES.—Holotype: USNM 151434b; figured paratypes: 151434a, c; unfigured paratypes: 151434b, d–j.

COMPARISON.—This species may be compared to those that have closely packed spines like a felt over the whole surface. *Acanthocrania densispina* has long slender spines and, in this respect, differs from *A. conferta*, which has short, stubby, stout spines. On the other hand, it differs from *A. minutispinosa* in which the spines are exceedingly fine and often difficult to see.

*Acanthocrania intermedia*, new species

PLATE 27: FIGURES 4–10; PLATE 30: FIGURES 25–27

Medium size for genus, subquadrate in outline with straight posterior margin and irregularly rounded sides. Profile poorly formed, usually low, misshapen cone, with apex from one-fourth to one-third length from posterior margin. Posterior slope short and steep. Anterior slope long but irregular, from flattened to fairly steep. Lamellae with long, delicate spines, about 3 per millimeter on anterior slope.

Brachial valve interior with large crowded adductor scars, moderately thickened and usually darker than surrounding shell. Posterior scars smaller and widely separated. Anterior marked medially by low boss or short ridge.

MEASUREMENTS (in mm).—

|                    | length | midwidth | surface<br>length | height |
|--------------------|--------|----------|-------------------|--------|
| USNM 706c          |        |          |                   |        |
| 151440a            | 9.0    | 9.9      | 11.0              | 4.3    |
| 151440c (holotype) | 7.4    | 8.2      | 8.5               | 2.1    |
| USNM 706           |        |          |                   |        |
| 151442a            | 7.9    | 8.6      | 9.0               | 2.5    |
| 151442b            | 6.9    | 8.0      | 8.5               | 2.7    |
| 151442c            | 7.7    | 8.1      | 8.5               | 2.0    |
| 151442d            | 6.4    | 7.9      | 7.5               | 2.4    |
| USNM 706e          |        |          |                   |        |
| 151444             | 8.0    | 8.1      | 11.5              | 4.9    |
| AMNH 506           |        |          |                   |        |
| 151439             | 7.5    | 8.2      | 8.0               | 2.7    |

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, and Appel Ranch members).

LOCALITIES.—China Tank: USNM 706c; Willis Ranch: AMNH 506, USNM 706, 706e, 723t, 724u; Appel Ranch: USNM 722t.

DIAGNOSIS.—Lamellose *Acanthocrania* covered with distantly spaced, moderately strong spines.

TYPES.—Holotype: USNM 151440c; figured paratypes: 151440a, b, 151442a; measured paratypes: 151439, 151440a, 151442a–c, 151444.

COMPARISON.—This species, because of the more scattered arrangement and fairly large size of spines, need be compared only with those similarly adorned: *A. magna*, *L. sparsispinosa*, and *A. regularis*, all new species. It differs from the first in having more numerous and much smaller spines; it is distinguished from the second by its more numerous and narrower lamellae and the more abundant spines; it is separated from the last by its stronger lamellae and generally less numerous spines, although they are of about the same size in the two species.

DISCUSSION.—This species is fairly common in the Willis Ranch Member of the Word Formation. It is usually a fairly low cone and the shape is rather uniform for attached shells; however, considerable variation can be detected in the height of the cones. Those from the China Tank (USNM 706c) assigned to the species are higher than is usual among the Willis Ranch specimens.

*Acanthocrania magna*, new species

PLATE 446: FIGURES 1–4

Large for genus, subtrapezoidal in outline, pos-

terior margin straight, sides broadly rounded, anterior margin nearly straight. Profile forming misshapen cone having short steep posterior side and long anterior slope. Apex rounded and about one-third of length from posterior margin. Surface marked by strong concentric growth lines and short stout spines. Interior with thickened muscle scars.

MEASUREMENTS (in mm).—Holotype: length 13.9, maximum width 17.6, surface length 18.0, height 6.2.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 726o.

DIAGNOSIS.—Large *Acanthocrania* with trapezoidal outline and coarse spines.

TYPES.—Holotype: USNM 153908.

COMPARISON.—The only species approaching this one in size is *A. vasta*, new species, but that is a lower, more irregular cone, much differently shaped, from the Cathedral Mountain species. It also is much larger and has smaller spines.

### *Acanthocrania minutispinosa*, new species

PLATE 28: FIGURE 44

Small for genus, subrectangular in outline with sides and anterior margin gently rounded; posterior margin straight. Profile conical with apex about one-fifth the length from posterior margin. Apex rounded. Posterior slope steep; sides steep and anterior slope convex. Surface not lamellose, covered by dense mat of minute spines, about 8 per millimeter in alternate rows.

Interior unknown.

MEASUREMENT (in mm).—Holotype: length 5.0, midwidth 4.0, surface length 7.0, height 3.4.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler and Pinery members).

LOCALITIES.—Hegler: AMNH 635; Pinery: USNM 725h, 725n.

DIAGNOSIS.—*Acanthocrania* with short, minute, matted spines.

TYPES.—Holotype: USNM 151447.

COMPARISON.—The abundance and extreme fineness of the spines of this species distinguish it from all others.

### *Acanthocrania platys*, new species

PLATE 28: FIGURES 14–16

Large for genus, almost square in outline with subparallel, slightly curved sides and nearly straight and nearly parallel anterior and posterior margins. Profile uneven, posterior depressed but anterior somewhat swollen, shape not strongly conical. Posterior slope short and moderately steep, occupying about one-fifth of valve length. Beak depressed, not prominent, protruding only slightly. Median region somewhat swollen; anterior slope steep. Surface marginally lamellose and covered by very fine spines numbering 6 to 8 in a linear millimeter.

Interior with moderately thickened and large anterior adductors, but small marginal adductor scars.

MEASUREMENTS (in mm).—Holotype: length 10, width 10, and height 4.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITY.—USNM 728f.

DIAGNOSIS.—*Acanthocrania* nearly square in outline with short posterior slope and fine, somewhat distant spines.

TYPES.—Holotype: USNM 151456.

COMPARISON.—This species in its square outline, short posterior slope and flattened form is unlike any of the other sparsely spinose species. It suggests the specimen from USNM 705a noted under *Acanthocrania* species, but that specimen has its fine spines forming a close mat, not separated as in *A. platys*.

### *Acanthocrania regularis*, new species

PLATE 30: FIGURES 20–24

Medium size for genus, crudely subquadrate in outline, sides and anterior margins rounded; posterior margin rounded; profile crudely conical, posterior slope steeper than anterior one, which is slightly convex. Beak small, smooth, located about one-fourth length from posterior margin. Surface finely lamellose, lamellae bearing rows of fairly large, stout spines.

Brachial valve interior with moderately large anterior adductors but small marginal adductor scars. Other details obscure.



## MEASUREMENTS (in mm).—

|                    | length | midwidth | surface<br>length | height |
|--------------------|--------|----------|-------------------|--------|
| 152572a            | 5.6?   | 6.9      | 6.2               | 3.0    |
| 152572b            | 6.4    | 6.6      | 7.6               | 2.6    |
| 152572c (holotype) | 6.6    | 8.1      | 9.0               | 3.7    |

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Rader Member).

LOCALITY.—USNM 725f.

DIAGNOSIS.—Finely lamellose *Acanthocrania* with moderately large, fairly regular stout spines, moderately crowded.

TYPES.—Holotype: USNM 152572c; figured paratypes: 152572a, b.

COMPARISON.—This species is distinguished from *A. intermedia*—the spines of which are about the same size as those of *A. regularis*—by their greater abundance and fairly regular size. It differs from *L. sparsispinosa* in having finer lamellae and much more numerous but smaller spines. Abundance and regularity of spines distinguishes *A. regularis* from *A. magna*.

*Acanthocrania vasta*, new species

PLATE 30: FIGURES 13–18

Exceptionally large for genus, subrectangular in outline, posterior line nearly straight, sides somewhat rounded and anterior margin crudely parallel to the posterior line. Profile usually low, poorly shaped, spreading cone. Posterior slope variable, not steep, forming about one-fifth of length; lateral slopes irregular; anterior slopes deformed in all specimens. Beak low, poorly defined. Surface covered by mat of short, closely crowded, fine spines, 3 to 5 per linear millimeter.

Interior of brachial valve with small anterior adductor scars, but large posterior scars along margin.

MEASUREMENTS (in mm).—Holotype: length 16.5, width 18.2, height about 6.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member, Lamar Member).

LOCALITIES.—Hegler: USNM 731; Lamar: 738b.

DIAGNOSIS.—Large *Acanthocrania* with depressed conical brachial valve having fine spines fairly closely crowded.

TYPES.—Holotype: USNM 152573; unfigured paratypes: 152573b–e.

COMPARISON.—This is the largest species of the

genus yet found in the Permian. Its low conical form, large size, and moderately dense spinose surface distinguish it from *A. conferta*, which forms a higher cone and stouter spines more densely crowded than those of *A. vasta*.

DISCUSSION.—This appears to be a variable species because some specimens have the spines more closely crowded than others, but they tend not to be densely matted. Shape, as usual with these cemented forms, cannot be relied on as a helpful character.

*Acanthocrania* species

Specimens were found at various localities in numbers too few to warrant specific names. They are noted below along with the chief characters that distinguish them.

LOCALITY USNM 701.—A small highly conical specimen (USNM 151448), with diameter of 5 mm and height of 2.8 mm, small crowded spines a feature in strong contrast to the Wolfcampian *Lepidocrania sparsispinosa*, new species.

LOCALITY USNM 701a<sup>3</sup>.—Several immature specimens of the above (USNM 151449).

LOCALITY USNM 701k.—A specimen of 3 mm diameter with characters of the two above (USNM 151450).

LOCALITY USNM 705a.—The single specimen (USNM 151453) from this locality is a large depressed cone with apex one-fourth the length from the straight posterior margin. It is 10.0 mm long and 10.6 mm wide and has a height of 2.6 mm. The anterior slope is long and gentle. The surface is covered by a mat of short stout spines, about 20? in a square millimeter on the anterior slope. Inside, the muscle scars are moderately thickened.

LOCALITY USNM 721g.—This is a small conical form (USNM 151455) with strong lamellae and crowded fine spines probably related to, if not the same as, specimens from USNM 701 and 701a<sup>3</sup>.

LOCALITY USNM 728f.—A fairly large but considerably misshapen brachial valve (151456) 11.2 mm long by 11 mm wide by 4.8 mm high with a lamellose surface and fairly strong scattered spines. The apex is about one-third the length from the posterior. All margins are irregular, the specimen evidently having been attached to a very irregular surface. The apex of the cone is not elevated, making for a very flat cone like that of *A. platys* from

the same locality. The different character of the spines of these two prevents placing them together.

LOCALITY USNM 725n.—Three misshapen cones (USNM 152574) with strongly lamellose exterior bearing distant, knoblike spines or nodes.

LOCALITY USNM 726o (Plate 27: figure 11).—Seven specimens (USNM 153046a–g) were taken from the residues of the bioherm at this locality. They are obviously young specimens, but they are characterized by a dense mat of long but very delicate spines. Type: Figured specimen USNM 153046a.

LOCALITY USNM 726x (Plate 27: figures 19–21).—Two specimens (USNM 153047a, b), a large high cone and an immature specimen, have low, stout spines. Figured specimen: USNM 153047a.

LOCALITY AMNH 500L.—A single well-formed low cone (USNM 151460). 5 mm long by 6.5 mm wide by 1.6 mm high, shows traces of thick spines. These are not prominent, but they appear to be sufficient to refer the specimen to *Acanthocrania*. It is lamellose, and a few plications run obliquely across the specimen from lower right to upper left, probably superimposed from the host.

### *Lepidocrania*, new genus

[Greek *lepidos* (scale) + *crania*]

Craniacea having the usual scabious habit and resembling *Crania* but with the exterior strongly lamellose or scaly, the scales or laminae bearing scattered stout spines.

TYPE-SPECIES.—*Lepidocrania tardispinosa*, new species.

COMPARISON.—This genus resembles *Petrocrania* in its form and habit but differs in having strong shingled lamellae. It also resembles *Acanthocrania* in the presence of spines on the exterior. In *Lepidocrania* the spines are few and scattered and are often concealed by the lamellae. In the type-species the spines are confined to the younger lamellae around the shell margin. In typical *Acanthocrania* the spines cover the shell in a dense mat, in some cases lending a feltlike surface to the specimens.

DISCUSSION.—*Lepidocrania* appears to be a rare genus. We have not seen specimens from other geologic periods that can be referred here. This may be a matter of preservation because the acid treatment lends itself well to revealing the delicate

lamellae, whereas specimens taken from shale or broken from limestone will have the lamellae torn off in collecting or worn off in weathering. The genus is uncommon in the Permian of West Texas, but continued dissolution of limestone from many localities should result in many more specimens and species.

### *Lepidocrania sparsispinosa*, new species

PLATE 28: FIGURES 1–13

Shell about medium size for genus, slightly wider than long with rounded to quadrate or rectangular outline. Profile variable but usually forming low cone with eccentric apex; posterior slope somewhat flattened and fairly steep; apex located one-sixth to one-third valve length from posterior. Lateral slopes moderately steep. Anterior slope fairly steep. Surface marked by distant overlapping lamellae and few stout, scattered spines.

Brachial valve interior with widely spaced marginal posterior adductor scars and with smaller, often thickened crowded anterior adductor scars. Pallial sinuses not determinable. Marginal rim narrow and poorly formed.

MEASUREMENTS (in mm).—

|                   | length | width | surface<br>length | height |
|-------------------|--------|-------|-------------------|--------|
| USNM 721g         |        |       |                   |        |
| 151438a           | 7.5    | 6.5   | 8.5               | 3.2    |
| 151438b           | 5.0    | 5.2   | 6.0               | 2.0    |
| 151402            | 8.0    | 9.6   | 8.5               | 1.7    |
| USNM 701c         |        |       |                   |        |
| 151401 (holotype) | 7.5    | 6.5   | 8.5               | 3.2    |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 4–12 of P. B. King).

LOCALITIES.—USNM 701, 701a<sup>3</sup>, 701c, 701d, 721g, 727e.

DIAGNOSIS.—Broadly and sparsely lamellose *Lepidocrania* with a few large, scattered spines.

TYPES.—Holotype: USNM 151401; figured and measured paratypes: 151402, 151438a, b.

COMPARISON.—This species is thinner-shelled and has more distant lamellae than either *L. sublamellosa*, new species, or *L. tardispinosa*, new species; furthermore, it does not have the angularity of outline and thick shell that distinguishes *L. sublamellosa*.

DISCUSSION.—*Lepidocrania* is rare in Wolfcampian strata. *Lepidocrania sparsispinosa* is repre-

sented by a number of immature individuals that are scaly and smooth, seldom with any trace of spines, which are a more adult feature.

*Lepidocrania sublamellosa*, new species

PLATE 29: FIGURES 20-40

Shell about medium size for genus and represented only by brachial valve; outline variable but generally quadrate, slightly wider than long and with angles usually rounded; profile varying from misshapen and rounded cone to broad and gently convex; apex usually broadly rounded, blunt and posteriorly situated about one-fourth to one-third the valve length from the posterior margin; posterior slope short and steep, forming flattened triangular area. Anterior slope long and gentle; lateral slopes steeper than anterior slope. Surface marked by closely overlapping concentric layers, last layer overhanging margin.

Brachial valve interior with thickened and flattened marginal rim; adductor muscles occupying the posterior, consisting of marginal small pair and larger pair just anterior to them. Anterior pair thickened and bosslike in many specimens. Pallial marks obscure, branch at midvalve extending laterally and sending trunk posteriorly and one anteriorly on sides; anteromedian region marked by low, short longitudinal boss or ridge.

MEASUREMENTS (in mm).—

|                    | length | midwidth | surface<br>measure | height |
|--------------------|--------|----------|--------------------|--------|
| USNM 706e          |        |          |                    |        |
| 151406a (holotype) | 8.8    | 9.3      | 11.5               | 4.0    |
| 151406b            | 8.9    | 9.6      | 12.5               | 3.7    |
| 151406c            | 8.2    | 9.6      | 12.0               | 3.3    |
| 151406d            | 8.0    | 8.4      | 10.0               | 2.6    |
| 151406e            | 8.4    | 9.7      | 10.0               | 2.2    |
| 151406f            | 6.6    | 7.0      | 10.0               | 3.0    |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Cherry Canyon Formation (Getaway Member), Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lens between the last two).

LOCALITIES.—Road Canyon: USNM 732j; Getaway: AMNH 519, USNM 728, 730, 732; China Tank: USNM 706c; Willis Ranch: AMNH 505, USNM 706, 706e; Lens: USNM 706b; Appel Ranch: USNM 715i, 722t; Word: USNM 737b.

TYPES.—Holotype: USNM 151406a; measured

and figured paratypes: 151406b, c, e, f; measured paratype: 151406d.

DIAGNOSIS.—*Lepidocrania* of medium size having a stout, thick shell with a broad marginal flattened rim and somewhat angulated outline.

COMPARISON.—The thick shell, broad margin, and angulated outline separate this species from *L. sparsispinosa*. These features, except the thick shell but less prominent lamination, help to separate it from *L. tardispinosa*, new species.

DISCUSSION.—A fairly large number of specimens of this species were taken from USNM 706e; nevertheless, it must be declared a rare form. The fact that an enormous amount of material was dissolved from this locality undoubtedly accounts for the large number of specimens, rather than abundance of occurrence.

*Lepidocrania tardispinosa*, new species

PLATE 27: FIGURE 1; PLATE 29: FIGURES 1-19;  
PLATE 30: FIGURE 19

Small to medium for genus, wider than long and roughly quadrangular in outline; profile variable, ranging from gently convex to narrowly and steeply conical, depending on the host; apex pointed in well-preserved specimens but generally rounded and blunt, located about one-third length anterior to posterior margin; posterior slope usually short but steep to precipitous; anterior slope long and gentle to steep; lateral slopes variable, usually steeper than anterior, but less so than posterior slope. Surface marked by numerous overlapping concentric layers, crowded at margins. Stout, blunt spires appearing on the youngest lamellae, but usually not numerous. Youngest layers often ragged. Margin thick and flattened in old shells.

Brachial valve interior with adductor muscle scars lightly impressed, anterior scars larger, stronger, and fairly well separated. Marginal rim wide, flat, prominent.

MEASUREMENTS (in mm).—

|           | length | midwidth | surface<br>length | height |
|-----------|--------|----------|-------------------|--------|
| USNM 702c |        |          |                   |        |
| 151395a   | 5.2    | 6.0      | 6.5               | 1.9    |
| " c       | 3.4    | 3.1      | 5.5               | 2.4    |
| " g       | 4.0    | 4.7      | 5.0               | 1.6    |
| " j       | 3.7    | 4.7      | 4.0               | 1.3    |
| " n       | 5.0    | 5.3      | 5.7               | 1.6    |

|                    | length | midwidth | surface<br>length | height |
|--------------------|--------|----------|-------------------|--------|
| 151395p            | 4.6    | 4.9      | 6.0               | 2.2    |
| " q                | 7.7    | 8.1      | 10.0              | 3.6    |
| " r                | 6.7    | 7.3      | 7.0               | 1.8    |
| USNM 720d          |        |          |                   |        |
| 151397a            | 7.7    | 8.8      | 10.0              | 3.6    |
| USNM 706f          |        |          |                   |        |
| 151427             | 5.6    | 6.2      | 7.0               | 1.8    |
| USMN 721z          |        |          |                   |        |
| 152582a (holotype) | 7.8    | 9.2      | 9.0               | 3.1    |
| 152582b            | 7.3    | 7.1      | 9.5               | 3.9    |
| 152582c            | 6.8    | 7.6      | 9.5               | 3.5    |
| USNM 724c          |        |          |                   |        |
| 152583a            | 7.6    | 7.9      | 11.0              | 4.1    |
| USNM 721u          |        |          |                   |        |
| 152581             | 7.6    | 6.6      | 8.5               | 4.6    |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 702, 702 (low), 721o, 721u, 727p; Road Canyon: 702c, 703c, 706f, 707e, 720d, 721j, 721s, 721y, 721z, 722e, 724c, 726d, 726x, 726z, 736x.

TYPES.—Holotype: USNM 152582a; figured paratypes: 151395a, j, o, 151427, 152581, 152482c, 152583; unfigured and measured paratypes: 151395c, g, n, p-r, 151397a, 151427, 152582b, c.

COMPARISON.—The thick shell, extremely scaly exterior, and high misshapen cones distinguish this species from *L. sublamellosa*, which is usually lower and more angular in outline. *Lepidocrania sparsispinosa* is separated readily by its smaller size generally, wider lamellae, and the few stout, scattered spines.

DISCUSSION.—The numerous specimens from USNM 702c help to make the growth of this species better known. The young are small, scaly, and have a smooth surface. Each new lamella is added under the preceding one as the shell enlarges. Depending on the surface of the host, the shells tend to spread out or become fairly high cones. In most specimens, spines are a late development and often are partially or wholly covered by the lamellae.

### *Lepidocrania* species

A number of specimens of this genus are represented by too few or too poorly preserved specimens to describe. These are annotated below.

LOCALITY USNM 703a<sup>1</sup>.—This is a fairly strongly

conical form (USNM 151416) with height of 3 mm, length of 7.5 mm, and width of 8.6 mm. Apex bluntly rounded, located one-third the length from the posterior; posterior slope short and steep, lateral and anterior slopes less steep.

Interior marked by large closely crowded anterior diductor scars and small more widely separated posterior ones; marginal rim narrow.

LOCALITY USNM 715v.—This is an eccentric cone (USNM 151454) with steep posterior slope and convex anterior slope with length of 6.2 mm, midwidth of 6.7 mm, and the height of 3.4 mm. It is strongly wrinkled, strongly lamellose, and has moderately long, distantly spaced spines. It is probably related to the smaller specimen (151421b) from USNM 728f listed below.

LOCALITIES USNM 728e, 728f (Plate 27: figures 27–29).—Two specimens each were found in residues from these localities. All are misshapen cones, three of them fairly large. All are lamellose, with the lamellae crowded marginally. The best preserved specimen is from USNM 728f and is quadrate in outline, the posterior margin straight. The apex is about one-fourth the valve length anterior to the posterior margin, and it is well rounded and low. The posterior slope is short and steep, but the anterior slope is long and moderately convex.

On the inside the muscles are crowded closely, the diductor scars small, the adductor scars large and forming thickened callosities. The antero-median region is marked by a low ridge in this specimen but not in the others. Measurements (in mm) of this specimen (USNM 151421a): length 8.5, midwidth 9.6, surface length 11.0, height 3.1. USNM 728e: 151410a, b; 728f: 151421a, b. Figured specimen: USNM 151421a.

LOCALITY USNM 728h (Plate 27: figures 30, 31).—This is a small misshapen cone (USNM 151445), strongly lamellose, and strongly like a small specimen from USNM 728f (151421b), but it differs in having fairly strong spines scattered distantly over the surface. Figured specimen: USNM 151445.

LOCALITY USNM 731-A.—Small flattened cone (USNM 152585) with apex near the posterior margin and somewhat squarish outline, with numerous, very strong, overlapping lamellae, which bear spines between them or on their edges. This is a very



distinctive form, but only one good specimen is known.

LOCALITY USNM 731-B.—This lot consists of several misshapen cones (USNM 152586) of various sizes up to about 7 mm, but no two of them are alike. They all have distantly scattered strong spines and lamellae.

LOCALITY USNM 736.—A single, small, rounded, low, eccentric cone (USNM 151423) with strong lamellae and, sandwiched between the layers, a few fairly long, stout, sharp spines. This may be related to specimens of the Pinery and Hegler members noted below.

LOCALITY AMNH 404.—This is a single specimen (USNM 151459) having very distinctive ornament but so distorted by unfavorable growth that it is best not described specifically. It is 3.8 mm long by 6.5 mm wide by 2.4 mm high. It is thus somewhat unnaturally rolled up in the direction of valve length. It is strongly lamellose, the lamellae strongly overlapping the one below. The lamellae bear distant, thick, and long spines on their posterior side, which protrude between the overlapping layers. This suggests affinities with the specimen mentioned under USNM 731-A.

### Genus *Petrocrania* Raymond, 1911

*Craniella* Oehlert, 1888:101.

*Petrocrania* Raymond, 1911:229.

*Lissocrania* J. S. Williams, 1943:71.

Several species and a few specifically unidentifiable specimens are referred to *Petrocrania* because they are devoid of spines and lamellae. Their chief ornament is concentric growth lines and growth wrinkles. A few of the specimens such as *P. teretis*, new species, are almost smooth and suggest Williams's genus *Lissocrania*. The type-species of this genus, however, conforms very closely to *Petrocrania*, as it has all of the characters of *Lissocrania* and seems indistinguishable.

*Petrocrania* is identified from Middle Ordovician rocks and extends well into the Permian, although it is rare in this period. In the United States few specimens have been reported, but it should be looked for in all acid residues and those resulting from sediment processing.

Like all craniids the exterior of *Petrocrania* has a variable form, nearly completely smooth to some-

what lamellose, but the degree of lamellation never reaches that of *Lepidocrania*.

### *Petrocrania diabloensis*, new species

PLATE 28: FIGURES 29-34; PLATE 745: FIGURES 29-34

Large, subcircular to somewhat quadrangular in outline; widest anterior to midvalve; posterior margin narrow and straight; sides well rounded; anterior margin broadly rounded. Profile depressed, broadly conical, apex off center and located about one-third the length from posterior margin. Posterior slope moderately steep; anterior and lateral slopes gentle. Surface marginally lamellose, otherwise without ornament.

Interior of brachial valve with small anterior adductor impressions and rather small marginal adductor scars. Anterior-median region marked medially by a low, rounded ridge.

MEASUREMENTS (in mm).—Holotype: length 13.7, maximum width 16.1, surface measure 15.0, height 4.0.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITY.—AMNH 625; USNM 728e.

DIAGNOSIS.—Large, poorly lamellose *Petrocrania* forming a fairly symmetrical but depressed cone.

TYPES.—Holotype: USNM 154103; figured paratype: USNM 152577.

COMPARISON.—This is the largest *Petrocrania* found in West Texas. It is distinguished from all other species described herein by this character and its unusually symmetrical form.

### *Petrocrania exasperata*, new species

PLATE 28: FIGURES 35-38

Shell thin, subcircular in outline, length and width about equal. Sides rounded to irregular; posterior margin nearly straight; anterior margin broadly rounded. Profile an unequal cone, posterior shorter than anterior side. Beak small, varying from nearly posterior to about one-fifth of length from posterior margin. Posterior slope steep. Anterior and lateral slopes irregular, moderately steep. Exterior lamellose but surface varying with host.

Posterior adductor scars large; anterior adductor scars smaller than posterior ones.

## MEASUREMENTS (in mm).—

|                    | length | maximum<br>width | surface<br>length | height |
|--------------------|--------|------------------|-------------------|--------|
| USNM 731           |        |                  |                   |        |
| 152578a (holotype) | 10.3   | 11.8             | 11.5              | 4.2    |
| 152578b            | 9.6    | 8.7              | 10.0              | 4.6    |
| 152578c            | 8.6    | 9.0              | 11.0              | 3.5    |

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler and Pinery members).

LOCALITY.—Hegler: USNM 731; Pinery: 725h, 736.

DIAGNOSIS.—*Petrocrania* of medium size with beak near the posterior margin.

TYPES.—Holotype: USNM 152578a; measured paratypes: 152578b, c.

COMPARISON.—This species is the next largest to *P. diabloensis*, but its unsymmetrical form, the strongly posterior position of the apex, and the less spreading habit distinguish the two. *Petrocrania exasperata* is larger and thinner shelled than *L. sublamellosa* and has softly rounded outlines, whereas *L. sublamellosa* is generally stronger angular, especially at the posterior. No septum appears in these Hegler specimens, and thus they are readily distinguished from *P. septifera*.

*Petrocrania septifera*, new species

PLATE 28: FIGURES 39–43

Small, squarish in outline with subparallel sides and subparallel anterior and posterior margins. Sides gently rounded; anterior margin nearly straight. Profile depressed conical; beak pointed, located about one-third of length from posterior margin; posterior slope short and moderately steep; anterior slope long and gentle. Surface strongly and regularly lamellose. Interior with large anterior scars and anterior half divided by low septum increasing in height anteriorly but not reaching margin.

MEASUREMENTS (in mm).—Holotype: length 5.2, width 6, height 2.0.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler and Pinery members).

LOCALITIES.—Hegler: USNM 731; Pinery: 725h.

DIAGNOSIS.—Flatly conical *Petrocrania* with lamellose surface and a median septum in the brachial valve.

TYPES.—Holotype: USNM 151422.

COMPARISON.—This species is distinguished from all others in the Permian by the presence of a median septum in the brachial valve.

*Petrocrania teretis*, new species

PLATE 28: FIGURES 17–25

Small, smooth, variable cones with rounded sides and anterior; posterior side usually straight. Cones varying from nearly flat to high and misshapen, usually low; beak off center, from one-third to two-fifths of length from posterior margin. Posterior slope gentle; median region somewhat swollen and having steeper sides than the long anterior slope. Surface smooth except for slight irregularities inherited from host. Anterior adductor scars larger than posterior adductors which are marginal.

## MEASUREMENTS (in mm).—

|                    | length | width | surface<br>length | height |
|--------------------|--------|-------|-------------------|--------|
| USNM 706b          |        |       |                   |        |
| 151404a            | 6.9    | 8.5   | 8.0               | 1.7    |
| 151404b            | 6.4    | 7.7   | 7.0               | 1.8    |
| 151404c            | 6.4    | 7.3   | 7.0               | 2.0    |
| USNM 706e          |        |       |                   |        |
| 151405a (holotype) | 7.7    | 8.7   | 9.3               | 2.6    |
| 151405a            | 6.8    | 7.4   | 7.0               | 1.7    |
| 151405c            | 5.1    | 5.8   | 5.3               | 1.4    |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (Willis Ranch Member and lens between that member and the Appel Ranch Member).

LOCALITIES.—Getaway: AMNH 512; Willis Ranch: USNM 706, 706e; Lens: USNM 706b.

DIAGNOSIS.—Small, subcircular, depressed conical *Petrocrania*.

TYPES.—Holotype: USNM 151405a; figured paratypes: 151404a, c; unfigured paratype: 151404b; measured paratypes: 151405b, c.

COMPARISON.—Differs from other described West Texas Craniidae in its completely smooth exterior surface.

DISCUSSION.—Most specimens of this species are very smooth and may be shells somewhat water-worn before silicification. They are smoother than usual with *Petrocrania*.

*Petrocrania* species

Specimens thought to be *Petrocrania* were found

at several localities listed below. They occur in insufficient quantity or quality of preservation for description. They are, therefore, only recorded with any significant facts about them that might be of use to the paleontologist or stratigrapher.

LOCALITY USNM 702un.—A small specimen (USNM 151415) with a diameter of about 3 mm. It is an eccentric cone with thick, flattened marginal rim.

LOCALITY USNM 708u.—This lot consists of four specimens (USNM 151417) that are small, flatly convex, broadly lamellose cones, obviously, immature, and not specifically definable. It is indeed possible that they are the young of *Lepidocrania*.

LOCALITY USNM 714w.—This locality yielded a small specimen (USNM 151418) forming a low cone with an apex less than one-third the valve length from the posterior margin and with rounded sides and anterior. The posterior margin is truncated and the posterior slope steep. The anterior slope is long and somewhat convex; the lateral slopes are short and steep. The exterior is not strongly lamellose and the surface is plicated by superposition of ornament details of the host.

On the interior, the posterior adductors are large and distant, but the anterior adductors are closely crowded. Pallial sinuses are not distinguishable.

LOCALITY USNM 721o.—This is a single small specimen, 4 mm long by nearly 5 mm wide. Its most striking feature is its wide posterior margin and steep, short, posterior slope in an otherwise very low cone (USNM 152575).

LOCALITY USNM 721u (Plate 28: figures 26–28).—Three small scabby, thin-shelled specimens (USNM 152579a) were taken from this place. Subcircular in outline, they form flat cones. The exterior is smooth (without spines), but it has inconspicuous growth lamellae and rounded bumps, probably reflecting the host. The posterior margin is slightly flattened, but the rest of the outline is well curved. Inside, the posterior adductors are large, but the anterior adductors are smaller but fairly large. The largest specimen is 6 mm long by 6.5 mm wide by about 1.5 mm high.

Three small scalelike specimens (USNM 152579) (Plate 28: figures 26–28) nearly circular in outline; one shows impressions of the host ornament.

Figured specimen: USNM 152579a.

LOCALITY USNM 722t.—A fairly high cone (USNM 152580) with nearly central apex has such uncertain exterior details that its generic affinities are difficult to place.

LOCALITY USNM 725f.—This locality is represented by three specimens (USNM 152576), two of which are fairly high cones, but the other greatly depressed. The largest specimen is 5.8 mm long by 5.2 mm wide. The beak is prominent but off center about one-third the length anterior to the posterior margin. The lateral and posterior slopes are steep, but the anterior slope is moderate. The exterior has a few undulations, but is devoid of other ornament. The interior fails to show detail sufficient to determine the muscle marks.

## Class ARTICULATA Huxley, 1869

### Order Uncertain

#### Suborder DICTYONELLIDINA Cooper, 1956

#### Superfamily EICHWALDIACEA Schuchert, 1893

#### Family ISOGRAMMIDAE Schuchert and Levene, 1929

#### Genus *Isogramma* Meek and Worthen, 1870

*Isogramma* Meek and Worthen, 1870:36.—Barrois, 1882:326.—Chao, 1928:32.—Paeckelmann, 1930:210.—Schmidt, Hermann, 1931:278–287.—Aigner and Heritsch, 1931:306.—Cooper, 1952:116.—King, R. E., 1931:64.  
*Aulacorhynchus* Dittmar, 1872:2.  
*Aulacorhyna* Strand, 1928:37.

*Isogramma* is a poorly known genus morphologically and its geological distribution is not clearly known. It ranges from Mississippian into Permian, but its occurrence in the Permian was not known until this century. Specimens are common in many parts of the United States in the Pennsylvanian, but it is not known in the Mississippian except in Alaska (Dutro, 1955). In some Pennsylvanian formations it is abundant, but good specimens are difficult to obtain because the shell is usually large, fragile, and is commonly found in friable shales. Consequently, its presence is revealed mainly by numerous fragments. It attains a large size in some formations of the Pennsylvanian and also in the Permian.

A few specimens have been obtained in the Glass Mountains and in related areas in the Sierra Diablo and Guadalupe Mountains. These indicate a considerable size range and a stratigraphic distribution from early Wolfcampian to Guadalupian (Getaway). Most of these specimens are fragments, but a few good brachial valves and a fragment of a pedicle valve (USNM 152566) aid considerably in understanding the genus.

*Isogramma* is unusual among the brachiopods for its broad, flat valves, the nature of the pedicle attachment, and the shell structure. The pedicle, beak regions, and shell structure of *Isogramma* are like those of *Eichwaldia* and *Dictyonella* of the Ordovician and Silurian to which it is related. A fourth genus is the aberrant *Megapleuronia* Cooper (1952), structurally like *Isogramma* but strongly plicated radially. These four genera are now placed in two families, which are sufficiently closely related to be united into a superfamily: the Eichwaldiaceae Schuchert (1893).

The pedicle valve of *Isogramma* is moderately convex, has a short interarea, and a plate depressed below the level of the exterior to which the pedicle is attached (Schmidt, 1931, pl. 10: fig. 10). The surface is marked by numerous crowded concentric elevated lines. Inside the brachial valve the depressed pedicle plate in some species forms a platform that probably was the site of adductor attachment, and the large diductor muscles are located adjacent to its sides. Teeth have not been seen; articulation was achieved by bearing of delthyrial angles of the palintrope against the sides of the cardinal process.

The brachial valve usually is moderately to strongly concave and is marked medially by a strong median septum, which, in the adult, is united to the shaft of a large, trilobed cardinal process. Laterally and anterolaterally sweeping "brachial ridges" reminiscent of those in the *Productidina* occur on each side of the cardinal process and median septum. The adductor scars have not yet been identified certainly.

The inner shell layer is perforated by closely crowded pores of varying sizes (Schmidt, Hermann 1931:281), thus constituting one of the most significant characters of the genus and superfamily. The punctae are not visible on the exterior.

### *Isogramma concavum*, new species

PLATE 25: FIGURES 16, 17

Small for genus, wider than long, width about twice length. Hinge straight, narrower than shell width. Sides narrowly rounded and anterior margin broadly rounded. Profile deeply concave, greatest concavity located in median region. Surface marked by closely crowded concentric undulations, about 7 or 8 in 5 mm at lateral margins.

Interior with strong median septum extending for two-thirds the valve length; cardinal process small with shaft moderately long; myophore narrowly trilobed. Other details obscure.

MEASUREMENTS (in mm).—Holotype: length 28.6, maximum width 62.8, hinge width 60.0?, height 7.0.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (bed 4).

LOCALITY.—USNM 727e.

DIAGNOSIS.—Small *Isogramma* with fairly strong ornament and deeply concave brachial valve.

TYPES.—Holotype: USNM 153188.

COMPARISON.—Differs from other Permian species in its deeply concave brachial valve.

### *Isogramma diabloense*, new species

PLATE 25: FIGURE 15; PLATE 26: FIGURES 5–15

Small, somewhat variable in outline, wider than long with narrowly rounded sides and subnasute anterior margin, general outline forming crude triangle in well-formed shells. Pedicle valve known from the beak region only. Brachial valve gently concave and marked by crowded concentric lines, about 5 in 1 mm at midvalve.

Pedicle valve with broad and short triangular pedicle plate and short, curved interarea.

Brachial valve with slender, bladelike median septum and long-shafted cardinal process with moderately expanded, medianly grooved, triangular myophore. Junction of shaft and median septum open, or closed. Brachial ridges not clearly defined.

MEASUREMENTS (in mm).—Holotype: length 14.4, midwidth 27.9, hinge width 23.4.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITY.—USNM 725y.

DIAGNOSIS.—Small, fine-lined, nasute *Isogramma*, with long-shafted cardinal process.



**TYPES.**—Holotype: USNM 151382b; figured paratypes: USNM 151382a, c, d.

**COMPARISON.**—Of described species this is most like *I. pachti* Dittmar from the Carboniferous of Russia, but it is not so strongly concave on the dorsal side, and the cardinal process has a much longer shaft and narrower myophore. The cardinal process and the fine ornament distinguish this species from *I. texanum* Cooper.

**DISCUSSION.**—The brachial valves of this species are well preserved, but only fragments of the posterior beak region of the pedicle valve were taken. These indicate a wide pedicle plate, not deeply inset because it does not appear as a platform on the inside. The exterior surface is marked by a median triangular mark that expands anteriorly. This surface is too vaguely marked to interpret. A short interarea is present, but no teeth can be identified.

The brachial valve is well preserved in the region of the cardinal process, but not elsewhere, because the brachial ridges cannot be identified; however, a curved line parallel to the posterior margin, which appears to separate two layers of shell, may be a trace of part of the brachial ridge. This line forms half of a V on each side of the median septum just anterior to the cardinal process. The characteristic cavity where the cardinal process shaft encloses the median septum is present on several specimens and exhibits the usual layered structure. One specimen shows the cardinal process shaft and median septum continuous, suggesting that this is the ultimate stage for these structures.

### *Isogramma lobatum*, new species

PLATE 24: FIGURES 1-4; PLATE 25: FIGURES 3-10

Species known from two brachial valves; large for genus, broadly subelliptical in outline; widest at midwidth. Sides narrowly rounded; median region sulcate, sulcus shallow, forming fold toward ventral side with marginal lateral folds in opposite direction. Exterior marked by fine concentric lines, about 3 per mm at posterior margin midway toward lateral margin.

Interior with strong, elevated median septum extending nearly to anterior margin, enclosed by anterior end of cardinal process shaft. Cardinal process broad and spreading, triangular outline, median lobe broad concave, lateral lobes narrow.

Brachial ridges (?) broad, extending laterally along posterior margin for two-thirds distance to lateral margin, then forming broad but narrow hook toward anterior margin.

**MEASUREMENTS** (in mm).—Holotype: length 47.4, midwidth 100.0, hinge width 72.4; paratype: length 41.9, midwidth 91.0, hinge width 81.4.

**STATIGRAPHIC OCCURRENCE.**—Cathedral Mountain Formation (*Institella* beds).

**LOCALITIES.**—USNM 702, 702b, 721u.

**DIAGNOSIS.**—Large *Isogramma* with lobate anterior.

**TYPES.**—Holotype: USNM 151384; figured paratype: 151383; figured specimens: 151387a, c-f.

**COMPARISON.**—This species is difficult to compare with others because the pedicle valve is unknown. No other species has the strong anterior folding of *I. lobatum*.

**DISCUSSION.**—Although only two specimens of this species are known, both of them show the dorsal interior in a remarkably good state of preservation. The cardinal process, brachial ridges, and median septum are better than in any other American specimens. The peculiar arrangement of the enclosure of the posterior end of the median septum by lateral growths from the cardinal process are shown to perfection. The enclosure is formed by at least three layers of shell. The cardinal process is broad and spreading, strongly trilobed, with the median lobe largest and fairly deeply concave. The lateral lobes are smaller and bounded by lateral notches that received the edge of the palintrope of the pedicle valve. The articulation is formed by the cardinal process.

The so-called brachial ridge is unlike that of the Productidina in its position and general form. It is much wider and is located considerably posterior to that of the Productidina. It appears to contact the posterior edge of the shell and then swings anterolaterally to form a broad loop. Its relationship to the adductor muscles is not known because none of the specimens shows any trace of these muscles. Traces of subradial pallial marks appear in the anterior part of the specimen.

### *Isogramma vidriense*, new species

PLATE 25: FIGURES 13, 14

*Isogramma millipunctata* R. E. King (not Meek and Worthen), 1931:65, pl. 10: fig. 8.



Small for genus, outline approximately semicircular, hinge almost equal to shell width which is about one-third length anterior to cardinal extremity. Sides narrowly rounded; anterior margin broadly rounded. Lateral profile gently convex; anterior profile broadly convex, maximum convexity at midvalve, lateral slopes long, flat and gentle. Concentric lines crowded, 5 in 7 mm near midvalve and gentle. Pedicle plate opening long and narrow, forming angle of  $18^\circ$ .

MEASUREMENTS (in mm).—Holotype: length 19.5, surface measure 24.0, maximum width 21.0, hinge width 20.5, height 5.0?

TYPE.—Holotype: YPM 10837; plaster casts: USNM 151385.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation, Neal Ranch Formation.

LOCALITY.—Gaptank: King 203; Neal Ranch: USNM 727d.

DIAGNOSIS.—Small *Isogramma* with long narrow pedicle plate having an apical angle less than  $20^\circ$ .

COMPARISON.—This species is distinguished by its small size and the long pedicle plate having an apical angle of only  $18^\circ$ .

DISCUSSION.—Only one good specimen of this species is known but its anterior margin is uncertain. Fragments of *Isogramma* occur rarely in the Neal Ranch Formation.

### *Isogramma* species

Specifically unidentifiable fragments of *Isogramma* were taken from the following localities:

AMNH 497.—A fragment of a large and thick-shelled species (USNM 151392).

AMNH 503=USNM 703 (Plate 25: figures 11, 12).—This is an exceptionally well-preserved fragment of the pedicle valve (figured specimen USNM 152566) preserving the beak region. It is the only silicified specimen of this part of an *Isogramma* taken from any of the residues. The exterior ornament is poorly preserved, but the pedicle area is well shown. This is a smooth area, depressed below the level of the surface, that forms an angle of  $24^\circ$  with the beak and expanding anteriorly. It is marked medially by a finely impressed line and transversely by fine horizontal lines. The apex of the angle at the beak is covered by shell, but just anterior to this smooth patch the median line is deep and two short lateral impressed lines appear.

The interarea is short and wide and the delthyrium is short and very wide, forming an obtuse angle (about  $112^\circ$ ). The interior region corresponding to the angular smooth region forms two shallow longitudinal troughs separated by a low ridge that probably corresponds to the impressed line of the exterior. The triangular area is bounded laterally by a low fold. Near the center of the triangular structure is a low longitudinal fold that divides the two long troughs. This median fold is marked centrally at about midvalve by a short impressed gash. Outside the bounding trough are two elongate areas interpreted as impressions of the subflabellate diductor scars. Marks on each side of the median fold are interpreted as part of the adductor scars. Internally the palintrope has no supports and no teeth were seen.

USNM 702k.—A fragment of a large specimen (USNM 152567) approaches the size of *I. renfrarum* Cooper from the Millsap Formation of north-central Texas. It measures 60 mm long and has a half measure of about the same amount in width (about 120 mm). No diagnostic features other than its large size are evident.

USNM 702n.—A very poorly preserved fragment of a brachial valve (USNM 152568).

USNM 705a.—A poorly preserved fragment of a small individual (USNM 151386).

USNM 720e.—This is part of a small and thin-shelled pedicle valve (USNM 151387).

USNM 720g.—Three fragments of a thick-shelled species were found at this locality (USNM 152569).

USNM 722-1 (Plate 24: figures 5, 6).—A small brachial (USNM 152570) valve, 11.4 mm long and 15 mm wide, represents the genus at this place. The ornament is of fine concentric lines as usual and the valve is anteriorly concave. On the inside the long shaft of the cardinal process is preserved, but the myophore has been broken off. The shaft reaches fully two-thirds the valve length from the posterior. This valve represents either a young example of a large species or a new species.

USNM 728 (Plate 25: figures 1, 2).—A fragment of the pedicle valve preserves the pedicle plate on the exterior, but it is not elevated on the interior. A well-developed palintrope is present, but no teeth appear at the delthyrial extremities as in the specimens from AMNH 503. No details of the musculature are revealed. Figured specimen: 151388.

USNM 728e.—Fragments of two specimens of moderate size are present from this locality (USNM 151389).

## Order STROPHOMENIDA Öpik, 1934

### Suborder ORTHOTETIDINA Waagen, 1884

Pedicle valve without functional pedicle and usually cemented apically in the young or throughout life; chilidium well developed in early members, usually poorly developed or absent in later genera. Cardinal process welded to brachiophores (=dentifers), with or without erismata (see definitions below); lophophore calcified in one late member; shell substance pseudopunctate. Mississippian to Triassic.

The number of genera and species in this suborder reached its maximum in the Permian. Perhaps nowhere in the world is the group so well represented as in the Glass Mountains. The abundance and preservation of these brachiopods exceed even that of the brachiopods from the famous Sosio Limestone of Sicily (Greco, 1938). Fourteen genera are known from the lower part of the Glass Mountains sequence, and the richest and most distinctive assemblage of genera is in the Neal Ranch Formation of the Wolfcamp Series. These brachiopods were for a long time classified under the Orthotetacea that embraced a number of related and unrelated genera.

Williams (1953) was the first to classify the Orthotetacea in detail when he proposed the superfamily, two new families, and one new subfamily. He also assigned here two already established families. This arrangement was a great advance over that of the past, but it did not last long, because the next year Stehli (1954) published a revision that threw out of the superfamily some of the elements Williams had assigned to it and Stehli added three new subfamilies. He removed the family Scacchinellidae from the Orthotetacea because of its numerous characters that relate it to the Productidina (Strophalosiacea) rather than to Orthotetacea.

Prior to Williams, Dunbar and Condra (1932) and Campbell (1957) discussed the classification and development of the orthotetaceans. The former authors, following Girty, based their views of subfamily Orthotetinae on the development of the

pedicle valve and the presence or absence of dental plates or median septum. Three groups were recognized: one with dental plates, one with a median septum in the pedicle valve, and a third without dental plates or septa. The cardinalia were given secondary consideration, but they were used on a generic basis to separate *Derbyoides* from *Derbyia*. Dunbar and Condra derived their phylogeny from the basic stock of *Schellwienella*, which they placed in the Silurian.

Campbell (1957:42), having the advantage of the prior work by Dunbar and Condra, Williams, and Stehli, discussed the classification of the Orthotetacea. He believes, as we do, that the production and elaboration of dental plates and septa have taken place independently in different stocks and a classification based entirely on structures of the pedicle valve is unnatural. Campbell recognized the value of the cardinalia and produced a possible phylogeny based on *Schuchertella* in the Devonian.

The classification by G. A. Thomas (1958) followed Williams in the main, but the new subfamily Derbyoidinae was added. Tinkering with the superfamily continued when, in 1960, Muir-Wood and Cooper removed the Gemmellaroiidae because they discovered anchor spines on this unusual genus. Later in the same year, Sokolskaja (in Osnovy, 1960) recognized in the superfamily three families and six subfamilies, one of them, the Omboniinae, proposed as new.

The classification proposed in the *Treatise* (Williams et al., 1965) submerged Orthotetacea by application of the rules of nomenclature in favor of Davidsoniacea. This classification does not take into consideration the different shell structure of some of the families and subfamilies. A basic difference exists between Davidsoniacea and Orthotetacea, the first one impunctate and the latter one pseudopunctate (or, rather, possessing taleolae). The Silurian and Devonian genera of the Davidsoniacea are without punctae or pseudopunctae, these include the Davidsoniidae and Fardeniidae. These also have different cardinalia from the Orthotetacea. Their cardinalia are strongly orthoid with well-defined brachiophores (= socket plates of Williams = dentifers). The sockets are excavated in the shell tissue and the teeth rest on the sloping face of the brachiophore (= dentifer). The structure described is more at home among the

Orthacea. We, therefore, separate the Davidsoniacea into a separate superfamily with two families, the Davidsoniidae and the Fardeniidae. This restores to the superfamily Orthotetacea (now credited to Waagen because of priority) some pseudopunctate forms, which characterize the Paleozoic above the Devonian. Further revision as given below is suggested by the types of cardinalia of the pseudopunctate genera.

A successful classification must consider a multitude of characters. This holds true for brachiopods as well as other organisms, and the failure to do so, with the resultant abortive classifications, is well illustrated by the Orthotetacea in which most family and subfamily arrangements have been based on features of the external ornament or on plates in the pedicle valve. The presence or absence of costae, costellae, or plications on the outside, in combination with presence or absence of dental plates, have been considered of paramount importance, to the near unanimous neglect of the brachial valve cardinalia as foundations for classification.

Campbell (1957) recognized the importance of the cardinalia in the derbyoid group. G. A. Thomas (1958) developed this theme further and employed it more broadly in classifying the Permian Orthotetacea of Western Australia. This is consistent with the views expressed by Ulrich and Cooper (1936:331) and Cooper (1970) on the taxonomic value of the cardinalia in the Triplesiacea and other brachiopods. Our studies of the Permian Orthotetidina of West Texas bring us to the conclusion that the group is much more successfully classified by basing the higher categories on brachial cardinalia than on ornament and dental plates.

Two major groups can be identified by the course of development of the lateral supporting plates of the cardinal process and of other minor features of the cardinalia. This major dichotomy does not alter the presently recognized subfamilies, but it aligns them differently and more consistently. We consider the difference in cardinalia so important that we are recognizing two superfamilies on that basis: Orthotetacea Waagen, 1884, and Derbyiacea Stehli, 1954. These are defined below and our revised classification is given below:

Order STROPHOMENIDA Öpik, 1934

Suborder STROPHOMENIDINA Öpik, 1934

Superfamily DAVIDSONIACEA, W. King, 1850

Family DAVIDSONIIDAE W. King, 1850

Genus *Davidsonia* Bouchard, 1849

?*Biconostrophia* Havlicek, 1956

*Pro davidsonia* Havlicek, 1956

Family FARDENIIDAE Williams, 1965

Genus *Fardenia* Lamont, 1935

*Gacella* Williams, 1962

*Chilidiopsis* Boucot, 1959

*Orthopleura* Imbrie, 1959

*Schuchertellopsis* Maillieux, 1939

*Hipparionyx* Vanuxem, 1842

*Xystostrophia* Havlicek, 1965

*Coolinia* Bancroft, 1949

*Iridistrophia* Havlicek, 1965

*Morinorhynchus* Havlicek, 1965

*Pseudostrophomena* Roomusoks, 1963

Suborder OTHOTETIDINA Waagen, 1884

Superfamily ORTHOTETACEA Waagen, 1884

Family ORTHOTETIDAE Waagen, 1884

Subfamily ORTHOTETINAE Waagen, 1884

Genus *Orthotetes* Fischer de Waldheim, 1829

*Streptopomum* Havlicek, 1967

Family SCHUCHERTELLIDAE Williams, 1953

Subfamily SCHUCHERTELLINAE Williams, 1953

Genus *Schuchertella* Girty, 1904

*Goniarina* Cooper and Grant, 1969

*Aerostrophia* Havlicek, 1965

*Drahanostrophia* Havlicek, 1967

*Serratocrista* Brunton, 1968

Subfamily HYPOPSINAE, new subfamily

Genus *Hypopsia*, new genus

Subfamily DIPLANINAE, new subfamily

Genus *Diplanus* Stehli, 1954

Subfamily DERBYOIDINAE G. A. Thomas, 1958

Genus *Derbyoides* Dunbar and Condra, 1932

*Tapajotia* Dresser, 1954

*Permorthotetes* G. A. Thomas, 1958

*Werriea* Campbell, 1957

*Brochocarina* Brunton, 1968

Subfamily PULSINAE, new subfamily

Genus *Schellwienella* I. Thomas, 1910

*Pulsia* Ivanov, 1925

Superfamily DERBYIACEA Stehli, 1954

Family ORTHOTETELLIDAE, new family

Genus *Orthotetella* R. E. King, 1931

Family DERBYIIDAE Stehli, 1954

Subfamily DERBYIINAE Stehli, 1954

Genus *Derbyia* Waagen, 1884\*

*Nothopindax*, new genus

*Licharewiella* Sokolskaya, 1960

Subfamily OMBONINAE Sokolskaya, 1960

Genus *Ombonia* Caneva, 1906

Family STREPTORHYNCHIDAE Stehli, 1954

\**Grabauellina* Licharew, 1934, *Pseudoderbyia*, Licharew, 1934, and *Derbyaeconcha* Licharew, 1934, are regarded as probable synonyms of *Derbyia*.

Genus *Aesopomum* Havlicek, 1965  
*Streptorhynchus* W. King, 1850  
*Kiangsiella* Grabau and Chao, 1927  
*Arctitreta* Whitfield, 1908 (= *Grumantia* Ustritsky, 1963)  
*Bothrostegium*, new genus  
*Tropidelasma* Cooper and Grant, 1969  
*Chelononia*, new genus

Family MEEKELLIDAE Stehli, 1954

Genus *Meekella* White and St. John, 1867  
*Niviconia*, new genus  
*Geyerella* Schellwien, 1899  
*Perigeyerella* Wang, 1955  
*Sicelia* Gortani and Merla, 1934  
*Orthothetina* Schellwien, 1900  
*Hamletella* Hayasaka, 1935

Family THECOSPIRIDAE Bittner, 1893

Genus *Thecospira* Zugmayer, 1880

DISCUSSION.—In many groups of brachiopods the current classification is only an approximation of the truth and many factors tend to qualify these classifications. Thus it is with the Orthotetidina, so complicated by a lack of knowledge of how the animals developed. This lack and its resultant uncertainty is shown in the classification in the proposal of Orthotetellidae for the genus *Orthotetella*, whose cardinalia are intermediate between the Derbyiidae and the Derbyoidinae. *Orthotetella* has a cardinal process that is in the stage of development of the Derbyoidinae, but it also has well-defined erismata that suggest relationship to the Derbyiidae.

A similar situation exists with *Tropidelasma*, but it is not so clean-cut as with *Orthotetella*. Most species and specimens have no erismata; the extensions from the anterior margin of the dentifers curve laterally to meet the side of the valve and produce a posterior trough. Some specimens, however, show traces of erismata, suggesting those of the Meekellidae or Derbyiidae buried in the callus that forms part of the sockets and cements the cardinalia to the valve wall. Two new species referred to *Tropidelasma*, *T. rhamphodes* and *T. robertsi*, have clearly defined erismata, not buried in callus but boldly exhibited as in the Derbyiidae. In *T. culmenatum* Cooper and Grant (the type of the genus) many of the young have clearly defined erismata, but these plates may be aborted or buried in the adult. *Tropidelasma gregarium* (Girty) has well-defined erismata in some specimens, in others they are clearly buried, but in still others, young and old alike, they appear to be aborted. In the later species such as *T. gregarium* most specimens

have the erismata aborted, the buttressing of the socket taking place by addition of shell material to the anterior edge of the dentifer, but instead of depositing along the whole side, it extends directly laterally to join the wall of the valve as a shelf, producing the troughlike structure along the posterior margin. We interpret this evolution as that of a gradual elimination of the erismata from a stock in which originally they were primary structures. In other words, they are converging toward the Schuchertellidae while maintaining an advanced forked cardinal process.

### Terminology of the Suborder Orthotetidina

Authors are not consistent in the definition of terms and often the same name is used for different structures. In order that the reader may know clearly the terms we are using in our treatment of the Orthotetidina, we list in this section our new names, their definitions, and the morphological terms that may cause confusion (see Figure 40).

*Brachial process* (or brachiophore). See *Socket plates*, *Socket ridge*, and *Dentifer*.

*Cardinal process*. The cardinal process of the Orthotetidina is variable and two major types may be distinguished: the schuchertelloid or orthotetid type and the derbyoid type. The former is more primitive, whereas the latter develops into the most complicated structure in the Derbyiacea, as illustrated by *Geyerella* and *Meekella*. The orthotetacean cardinal process, like that of the strophomenids, has two lobes that are not strongly developed in the orthotetids and schuchertellids, but that become extravagant in the derbyias and meekellas. The cardinal process of the schuchertellids generally does not have a single shaft, but that of the derbyoids has a prominent wide shaft terminating in long divergent prongs that bear the myophore, usually median slits on the prongs. Generally the length of the cardinal process is determined by the depth or thickness of the pedicle valve but the basic form of the process, whether orthotetacean or derbyiaceous, is not affected.

*Chilidial boss*. A vestigial form of the chilidium is preserved in some late members of the Meekellidae; it produces a monticulus in deep-shelled species.

*Chilidium*. This structure is a variously developed plate at the apex of the dorsal valve, some-



what modified in form from the characteristic arch over the notothyrium of strophomenoid brachiopods. In the schuchertelloids the notothyrium is reduced or has disappeared, but the chilidium is a low arch, usually with a median trough at the apex of the brachial valve. It normally is firmly connected with the posterior part of the cardinal process. The median trough in the chilidium often scores the pseudodeltidium of the pedicle valve, producing a groove along the crest of this plate. The trace of the groove shows on the inside surface of the pseudodeltidium as a low ridge. Young *Derbyia* has this type of chilidium, and a groove in the pseudodeltidium is a common feature; it also shows in *Bothrostegium*. In the later development of *Derbyia* many adults fail to show any trace of a chilidium. In *Meekella* and other genera with a strongly keeled cardinal process-shaft the chilidium is reduced to a chilidial boss, a small round plate at the apex closing the gap between the monticulus and the dorsal apex.

*Dental plates.* In the Orthotetacea and Derbyiacea, as in other brachiopods, it is important to distinguish between primary and secondary plates. *Meekella* and *Geyerella* have genuine primary dental plates that are part of the shell in its earliest stages (many minute specimens in the collection can be identified as *Geyerella* or *Meekella* by their separated dental plates or their spondylium). The dental plates that form the minute spondylium of *Orthotetes* are present in very early stages. This is not true, however, of *Derbyia*, which often produces an apical chamber simulating that of *Orthotetes* in late stages of growth. The plates producing this chamber in *Derbyia* are a feature of adult growth and are secondary, often unequally developed or on one side only, appearing individually rather than as a specific characteristic. Secondary dental plates are produced in some schuchertellids of the Mississippian by adventitious growth from the dental ridges to the valve floor. Some species of nonpseudopunctate "schuchertellids" in the lower Devonian also exhibit this phenomenon. These have been referred to *Schellwienella*, but that assignment certainly is incorrect. The so called spondylium in *Permorthotetes* appears to be a secondary structure and the genus is a valid separation from *Orthotetes*, but its relationship to *Derbyoides* has not been established definitely. It thus is apparent that

the varying nature of dental plates must be determined before generic assignments can be made with confidence.

*Dental ridges.* These are the growth tracks of the teeth, which show as ridges under the delthyrial edges of the palintrope when dental plates are absent. Depending on the size of the teeth, these may be strong or weak.

*Dentifer.* This is a new name suggested for the vestigial brachiophore that occurs in the Orthotetacea. The name *brachiophore* was not a happy selection because the structure probably never was a support to the lophophore, as Williams (1953:9) pointed out. Actually it probably served a dual purpose in the orthids, where it was the sloping face of the socket, forming the inner wall, and must also have been associated with the lophophore, probably its support. The brachiophore occupies essentially the same position as the crural base of the rhynchonellid, which extended as the cura into the valve and determined the position of the body wall where the lophophore is attached. The crus did not support the lophophore either but did define its position. The brachiophore probably served the same purpose and was one of the supports of the body wall; the mouth was located on the body wall between the ends of the brachiophores.

The brachiophore of orthaceans lies under the edge of the notothyrium, and the edge of its free extremity supported the tooth of the pedicle valve. The brachiophore (called *socket plate*, later called *socket ridge*—*Treatise*, page H 153—by Williams) can be detected in the Strophomenida, where it frequently forms a small rod under the notothyrial edge and is associated with articulation. The same rodlike structure occurs in the impunctate Davidsoniacea and forms a more conspicuous element of the cardinalia. Here it must have functioned in the same manner as the orthid brachiophore. Unlike the orthids, the brachiophore of the Davidsoniacea tends to be buried under adventitious shell laid down on its inside and anterior side, welding it to the cardinal process and walling in the anterolateral extremity of the socket to produce a cuplike structure (*socket plate*, in part, of G. A. Thomas, 1958:9).

In the Orthotetacea, pseudopunctate homeomorphs of the Davidsoniacea, the brachiophore is still present, but it is much obscured by adventitious



shell, although usually it can be seen with little difficulty. Later Orthotetaceans are characterized by longer and forked cardinal processes. The more primitive orthotetaceans are very similar to the Davidsoniacea as can be seen in *Schuchertella* (sensu stricto) and *Derbyoides*. In the Derbyiidae, however, the cardinal process begins to lengthen and bifurcate, and the brachiophore (i.e., dentifer) appears as an oblique ridge on the long sloping face of the erisma, which is welded to the cardinal process shaft. In this group of brachiopods the dentifer may (or may not) extend anteriorly to the edge of the erisma and thus simulate a brachiophore or crus.

In the Meekellidae the dentifer evolves into a complicated combination of plates called the *promontorium* (q.v.). Although the promontorium may not once suggest the brachiophore or dentifer, its development can be followed in various juvenile stages from a simple ridge like the dentifer to the complicated promontorium.

*Erisma*. This name is suggested for the plates supporting the cardinal process and dentifer. These are the socket plates of G. A. Thomas (1958:19, figs. 6*b*, *c*), which are clearly extensions from his socket ridge, which buttresses the socket plate. They are not the same as the socket plates of the Schuchertellidae (G. A. Thomas, 1958:18, fig. 5). Erismata are present in the youngest stages of the Derbyiidae and Meekellidae and thus are unlike the socket plates of the Orthotetidae and Derbyoidinae, which are secondary and achieve their greatest development in large or old specimens. Erismata are conspicuous in the Derbyoidinae, Streptorhynchidae (except *Tropidelasma*), and Meekellidae. They are present in *Orthotetella*, but they are anomalous in supporting a retarded cardinal process without shaft and bifurcated myophore. Perhaps the largest development of the erismata is in *Ombonia*.

Some of the schuchertellids develop secondary erismata and thus come to mimic the interior of the Derbyiidae. To prove this, the student must seek young specimens to determine the primitive condition of the cardinalia.

The opposite condition has been detected in one species, *Tropidelasma gregarium* (Girty), in which the erisma is partially or in some specimens wholly eliminated by deposition of adventitious shell.

Enough specimens show the erisma clearly to make certain the identification of the species.

*Fulcral plates*. These are small curved plates located at the proximal end of the socket, defining small cavities into which the teeth are inserted. They are not universally present in the Orthotetacea but are very well developed in Meekellidae to add to the complexity of their cardinalia. These are definite and separate plates and are not simply excavations in adventitious shell.

*Gusset*. The plate uniting the dentifer to the cardinal process shaft.

*Keel*. The angular edge of the posterior side of the cardinal process shaft in the Meekellidae.

*Monticulus*. The small, longitudinal, narrowly rounded fold on the median part of the pseudodeltidium in the Derbyiacea such as *Tropidelasma*, *Meekella*, and *Geyerella*. This usually appears on shells having elongated palintropes in which the pseudodeltidium is initially convex but becomes flat in adult stages. The monticulus is the growth track of the indentation at the distal edge of the pseudodeltidium produced by a fold accommodating the keel or the chilidial boss.

*Myophore slits*. Deep longitudinal slits on the distal end of the prongs of the cardinal process. These are usually internally crenulated and evidently were the site of diductor muscle attachment.

*Perideltidium*. A narrowly triangular region on the interarea outside the pseudodeltidium but not reaching the posterolateral margins, which is ornamented differently from the remainder of the interarea and is separated from it by a more or less distinct line. The perideltidium commonly is ornamented by longitudinal lines as well as the usual concentric growth lines that parallel the hinge margin. It normally is well developed on *Derbyia*, but it was not observed on all of the Orthotetidina treated herein.

*Promontorium*. This is a structure variously developed in the Meekellidae and best seen in *Niviconia globosa* (R. E. King). It is located on the laterally sloping face of the cardinal process and is a development from the dentifer (*socket ridge* of authors) combined with the gusset, which is concave in *N. globosa*. It forms a more or less horizontal shelf over the lateral interior of the valve. In *Meekella* the proximal end of the promontorium is thickened and forms the inner edge

of the socket opposite and above the fulcral plate.

*Septa.* A variety of septa appear in the Orthotetidina, but the median septum of the pedicle valve has perhaps most significance. Septa may be primary or secondary. The septum of *Derbyia*, for example, appears in minute specimens and is taken to be a primary structure. The so-called septum of *Derbyoides* appears to be secondary (*euseptoidum* of Fredericks 1927b:2), appearing only in adults, fairly strongly in some, but not present in the young. This is probably true also of *Permorthotetes*, but we have not seen young specimens to substantiate the point. A distinction, but a difficult one, may be made between septa and ridges. We call a *septum* the strong distinct vertical plate of *Derbyia*, but we would term the secondary structure illustrated in *Permorthotetes* and *Derbyoides* a *median ridge* because it is low and more in the nature of a myophragm. We would also call the median ridge appearing in the brachial valve of *Tropidelasma* and some other genera a *myophragm* rather than a median septum.

*Socket plates.* As presently employed in Orthotetidina by G. A. Thomas (1958:9), the term *socket plates* seem to us to refer to two types of plates. For one of these we have coined the term *erisma* to be applied to the widely divergent plates of Derbyiidae and Meekellidae that support the cardinal process and form an arch posterior to the adductor field. These appear to be primary structures because they occur in the very young. They are not the same structure to which Thomas has applied the term socket plates in the Schuchertellidae. These schuchertellid plates are secondary and are deposited on the inside of the dentifer (*socket ridge* of Williams) and the anterior side of the socket to form a cuplike socket wall, which is the most conspicuous mark of the Schuchertellidae and Orthotetidae.

Neither of the examples above accord with Williams' first use of the term *socket plate* or his later modification called *socket ridge*, nor are they like the socket ridges of the Rhynchonellida, Spiriferida, and Terebratulida to which we would restrict the term. These terms refer to the *brachiophore* of Schuchert and Cooper to which we apply the name *dentifer* to be used in the Orthotetacea.

*Socket ridge.* Originally called *socket plates* by Williams (1953c:9), they were later referred to as

*socket ridges* (*Treatise*, page H153). Williams pointed out that these structures, which were called *brachiophores* by Schuchert and Cooper, actually are not lophophore supports but are more concerned with the articulation. Although *socket plates* or *socket ridges* aptly define these plates, the terms conflict with the socket ridge of the cardinalia of the Rhynchonellida, Spiriferida, and Terebratulida, which are not the same structures. If there is an homology, the brachiophore is the crural base of the Rhynchonellida and Terebratulida, but that is not a socket ridge (see Thomson 1927:85). In order to avoid confusion, we prefer to use the new term *dentifer*, which implies the function as well as identifies the plate in the Orthotetacea.

*Spondylium.* The union of the primary dental plates with a median septum produces a spondylium. It is important to distinguish between a primary spondylium such as that of *Orthotetes*, *Ombonia*, and *Geyerella* from that of *Derbyia* and *Permorthotetes*, which, when present, is a secondary structure.

### Superfamily ORTHOTETACEA Waagen, 1884

Orthotetidina without erismata.

#### Family ORTHOTETIDAE Waagen, 1884

Orthotetacea having well-developed dental ridges, a median septum with short spondylium, and, in some genera, short apical plates or false apical plates forming a small chamber.

#### Family SCHUCHERTELLIDAE Williams, 1953

Early progressive Orthotetacea having cuplike sockets, well-formed chilidium and variable delthyrial chamber.

#### PULSIINAE, new subfamily

Schuchertellidae with dental plates. Subfamily based on *Pulsia* Ivanov, 1925, from the Carboniferous.

#### Subfamily SCHUCHERTELLINAE Williams, 1953

Schuchertellidae without dental plates, spon-

dylum, or median septum in the pedicle valve and with recurved cuplike secondary plates forming the sockets in the brachial valve.

Genera in the Glass Mountains: *Schuchertella* and *Goniarina*.

### Genus *Schuchertella* Girty, 1904

*Schuchertella* Girty, 1904:734.—Weller, 1914:53.

Ranging from small to large, usually biconvex, pedicle valve having greater depth; hinge wide, variable; interarea variable, usually prominent; anterior commissure variable; pseudodeltidium strongly convex; perideltidial area well developed. Surface usually finely costellate.

Pedicle valve interior without dental plates but with strongly developed dental ridges. Muscle field roundly flabellate; with large diductor scars and enclosed adductors; myophragm usually not strongly developed.

Brachial valve interior with short bilobed cardinal process and prominent chilidium; myophore lobes with wide furrows; brachiophores (=dentifers) appearing as flat blades surrounded by shell tissue to form cuplike sockets, and forming sloping inner face of 'socket. Adductor field large, subcircular, usually deeply impressed, divided medially by a poorly developed median ridge. Pallial marks seldom visible.

TYPE-SPECIES.—*Streptorhynchus lens* White (1862:28).

DISCUSSION.—Three features are of prime importance in the understanding of *Schuchertella*, which has given its name to an important family of brachiopods: (1) the shells are pseudopunctate and thus distinguished from most Devonian forms bearing this name; (2) dental plates are absent; and (3) the dentifers are vestigial, surrounded by callus (socket plates), and do not have anterolateral extensions, a considerable distinction from some later genera.

*Schuchertella* has been identified in Permian rocks by Stehli (1954:298). These and Pennsylvanian forms like them (*Streptorhynchus affine* Girty) are placed by us in a new genus *Goniarina* because of differences in both valves and a difference of exterior shape. One Permian species, however, *Schuchertella subvexa*, new species, cannot be assigned to *Goniarina* and is placed in *Schuchertella*

in spite of some differences from the type-species.

*Schuchertella subvexa* is more conical than usual with typical *Schuchertella* and the interarea is longer than usual, but the interior of the pedicle valve has no dental plates, and no median ridge or myophragm is developed. This valve seems to be assignable only to *Schuchertella*. The brachial valve is not entirely typical of *Schuchertella*, but it is sufficiently like it to warrant the use of the name, at least until more material can be found. The cardinal process, however, has unusual features.

The cardinal process has characters that make it transitional between *Schuchertella* and *Derbyia*. The chilidium is bilobed as in *Derbyia*, but this seems not to have affected the pseudodeltidium. The dentifer is not clearly visible in any of the specimens. The myophore is schuchertellid in its brevity and wide myophore slits, but the lateral plates that buttress it are widely divergent, thin, and bear an oblique ridge about halfway toward their distal extremity, the similar-appearing ridge in *Derbyia* and other genera. The muscle marks are clearly impressed.

### *Schuchertella? subvexa*, new species

PLATE 32: FIGURES 1-5; PLATE 33: FIGURES 1-26

About average size for genus; biconvex to planoconvex to shallowly or moderately conical, normally not distorted; outline transversely semielliptical to semicircular; hinge normally forming widest part of shell, but slightly narrower than midwidth in some specimens; commissure rectimarginate to gently sulcate; costellae moderately high, crests rounded, weakly to strongly crenulate by intersection with fine concentric ornamentation, added anteriorly by insertion, averaging about 14 in 5 mm on pedicle valve, 16 in 5 on brachial valve, younger costellae normally weaker, intertroughs slightly narrower than costellae; growth lines weak, nearly uniformly spaced.

Pedicle valve flatly semiconical, apex pointed or blunt; lateral profile gently convex to concave; anterior profile broadly and flatly convex; interarea normally flat to slightly concave or convex, commonly apsacline, asymmetrical; pseudodeltidium completely arched, dorsally expanding; perideltidial area obscure, its limits normally nearer edge of interarea than midline.

Brachial valve flat to slightly convex, with very narrow interarea, commonly disappearing before reaching hinge ends; anteromedian region of adults sulcate, sulcus wide and shallow; cardinal extremities flattened.

Pedicle valve interior with small teeth extending apically as dental ridges and meeting at apex; no median septum. Valve floor with rather deep striations becoming deeper near margins.

Brachial valve interior with short, straight, bilobed cardinal process projecting posteriorly from beneath thick childium; lobes widely longitudinally

grooved; dentifers rudimentary, imbedded in thick callus continuous with sides of cardinal process; dentifers widely diverging and projecting into body chamber, laterally fused to shell wall by short, thin callus, bounding wide sockets. Muscle area short, occupying between one-fourth and one-third valve length, weakly delimited, may be bisected by low rounded median ridge; muscle marks faintly impressed longitudinal striae and ridges. Floor of valve moderately deeply striated, striae becoming deeper near margins.

MEASUREMENTS (in mm).—

|                    | brachial<br>valve<br>length | midwidth | hinge<br>width | thickness | length<br>inter-<br>area | brachial<br>valve<br>length |
|--------------------|-----------------------------|----------|----------------|-----------|--------------------------|-----------------------------|
| 152589a            | 4.0                         | 5.8      | 5.3            | 3.3       | 2.2                      | 4.0                         |
| 152589b            | 6.5                         | 6.6      | 5.8            | 5.0       | 3.7                      | 5.2                         |
| 152589c            | 7.5                         | 9.7      | 8.6            | 3.5?      | 3.2                      | 6.9                         |
| 152589d            | 11.2                        | 11.2     | 11.0           | 6.0       | 6.4                      | ?                           |
| 152589e            | 13.1                        | 15.7     | 16.2           | 5.3       | 6.4                      | ?                           |
| 152589f            | 17.3                        | 18.2     | 19.0           | 6.0       | 8.0                      | ?                           |
| 152589g            | 5.7                         | 22.8     | 23.0           | 10.9      | 10.9                     | ?                           |
| 152589h (holotype) | 25.0                        | 26.0     | 22.0           | 7.6       | 11.3                     | ?                           |
| 152589i            | ?                           | 21.0     | 21.0           | ?         | ?                        | 14.7                        |
| 152589j            | ?                           | 14.0     | 9.4            | ?         | ?                        | 12.0                        |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of bed 2 = the Gray Limestone of King).

LOCALITY.—USNM 701.

DIAGNOSIS.—Moderately large *Schuchertella* with long interarea and delicate cardinalia.

TYPES.—Holotype: USNM 152589h; figured paratypes: 152589b, e, f, g, i, j, k; measured paratypes: 152589a–g, i, j; unfigured paratypes: 152589a, c, d, l–v.

COMPARISON.—This is the only species in the Glass Mountains referred to *Schuchertella*. It is characterized by its wide hinge, shallow and conical pedicle valve with long apsacline interarea, strong external costellae, and internal striae. It differs from *Goniarina pyelodes*, new species, which also occurs in the Neal Ranch Formation, in its larger size, stronger costellation, more flatly conical and anteriorly expanding or spreading pedicle valve, and proportionately thinner shell and narrower brachial interarea. These features also distinguish it from *Goniarina futilis*, new species, from the Leonard of the Glass Mountains. It differs from *Goniarina permiana* (Stehli) from the lower Bone Spring of

the Sierra Diablo and lower Skinner Ranch of the Glass Mountains in its flatter, less cup-shaped pedicle valve, larger average size, posteriorly projecting interarea, stronger costellation, and lack of an anteromedian node in the brachial muscle area.

DISCUSSION.—*Schuchertella subvexa*, a rare species, probably grew attached to some foreign object by the tip of its pedicle beak. Attachment marks on most specimens are small, not deeply impressed, and are near the apex. The shell may be slightly distorted, normally by twisting or by asymmetrical growth, but the amount of distortion is not sufficient to suggest that it lived in closely crowded clusters.

### Genus *Goniarina* Cooper and Grant, 1969

*Schuchertella* Dunbar and Condra (not Girty), 1932:117.—Stehli, 1954:298.

*Streptorhynchus* Dunbar and Condra (not W. King), 1932:121.

*Goniarina* Cooper and Grant, 1969:2.

Small, semiconical, with long interarea; generally attached by part of pedicle valve when young but



living free in adult stage. Valves unequal; brachial valve flat to slightly convex, pedicle valve deep. Anterior commissure rectimarginate. Perideltidal area developed. Surface costellae, costellae narrow and rounded, commonly with strong fila. Pseudopunctate.

Pedicle valve interior with deep delthyrial cavity and long teeth; no dental plates; muscles lightly impressed.

Brachial valve interior with cardinal process bilobed, lobes medially grooved and separated by thin median septum, and all fused into a thick curved plate covered by arched chilidium; dentifers long, laterally compressed and distally pointed. Adductor field subcircular, usually surrounded by thickened rim and medially divided by short, often club-shaped ridge extending anterior to muscle field margin.

TYPE-SPECIES.—*Goniarina pyelodes* Cooper and Grant (1969:2, pl. 4: figs. 26–30).

DIAGNOSIS.—*Schuchertella*-like but having median ridge of brachial valve anterior to adductor muscles.

COMPARISON.—*Goniarina* differs from *Schuchertella* in its external form and minor details of the interior; it has some features of *Schuchertella* and some *Streptorhynchus*, but it is sufficiently different from both to be separated as a new genus. Externally *Goniarina* suggests *Streptorhynchus* in the attached habit and the elongated interarea. This is usually not so long as in the longest of the streptorhynchids, but it is generally longer than in most schuchertellids. Furthermore, the cardinal process of the brachial valve of *Goniarina* is unlike the elongated forked structure of *Streptorhynchus* with its erismata.

Typical *Schuchertella* is generally biconvex, the pedicle valve typically deeper but not strongly conical. *Goniarina* is more conical than *Schuchertella* and has an elongated and usually flat interarea. The pseudodeltidium in both genera is strongly arched and the dental plates are undeveloped. The muscle scars of *Goniarina* are so lightly impressed that they cannot be revealed except by the trace of a broad myophragm, which can be seen in some specimens. The cardinal processes of the two genera are similar, both having the lobes welded into a solid structure. In *Goniarina* a small median septum divides the lobes. Unlike *Schuchertella*, this

new genus has extremely long, slender and flattened dentifers, unusual for the Orthotetacea. The sockets are large. An important difference between the two genera is the presence of an irregular myophragm or ridge that arises between the adductors and extends anterior to the raised periphery of the muscle scar to about midvalve. This type of structure is not seen in *Schuchertella*, in which the myophore, when present, is a broad rounded ridge extending from just anterior to the cardinal process to the anterior end of the adductor field; it is not extended anteriorly out of the adductor field.

The shape of the shells, the elongated palintrope of the pedicle valve, and the elongated, nonenclosed dentifers without erismata separate *Goniarina* from *Derbyoides*.

DISCUSSION.—The pedicle valve of *Goniarina* does not offer any unusual characters calling for discussion. The brachial valve, on the other hand, contains the important generic characters. The dentifers are longer than in *Schuchertella* and allied genera, and they are not enclosed to form cuplike structures as in *Derbyoides*. The elongate character of these plates persists throughout the life of the animal. In the very young they are long and slender, but, as in the adults, they are buttressed from below by adventitious shell.

The median ridge anterior to the adductor scars is variable, ranging from a slender ridge to a club-shaped structure with its thickened end extending free into the mantle cavity. Many brachial valves have the margin of the adductor field thickened. The thickenings take the form of radial ridges and, in some examples, of thick projections forming serrated rims. This genus is strongly pseudopunctate and some of the taleolae are arranged along the hinge in a horizontal row, suggesting a crude form of dentition for articulation of the valves.

This genus is generally rare and insignificant except at one or two places. *Schuchertella pratteni* (McChesney) and *Streptorhynchus affine* Girty are placed in this genus, thus extending its range into the Pennsylvanian. In the Permian it is fairly common at one place in the Sierra Diablo, where it occurs at the base of the Bone Spring Formation. In the Glass Mountains it is found in the Wolfcamp and throughout the Leonard.

The species of *Goniarina* are variable in size and shape. Some are like the type *G. permiana* (Stehli),



strongly conical with deep pedicle valves. Two or more species in the Glass Mountains are unlike these and are somewhat more like the type-species of *Schuchertella*, *S. lens* (White). The shells are shallow and unequally biconvex, the pedicle valve generally being deeper and somewhat broadly semiconical. These species, as evidenced by the few good specimens and fragments of others, attained fairly large size, rivaling some of the flatter derbyias or *Derbyoides*. These species have proved so rare that not much is known about them. It was thought at first that these large forms might be the adults of the smaller forms, but the growth and resulting shape of the shell are different. These aberrant forms of *Goniarina* ultimately may form a separate genus, but, as we view them now, they are only larger and flatter forms of *Goniarina*.

Stehli (1954:298) depicted this genus as having been attached to shells or to solid objects by the apex. Several specimens in the national collection remain attached by a portion of the ventral surface rather than by the apex. Furthermore, none of the pedicle valves show scarred apices, but many of them have flattened areas on which the costellae that were the areas of attachment are not developed. It seems most likely that the majority lived loose on the sea-floor after having been ripped from their original moorings.

### *Goniarina appeli*, new species

PLATE 42: FIGURES 1-5

Small for genus, outline subrectangular, hinge widest and extended into minute ears. Sides and anterior broadly rounded, profile hemipyramidal. Interarea of pedicle valve strongly apsacline. Pseudodeltidium strongly arched; anterior commissure slightly folded ventrally. Surface marked by costellae of uneven size, about 3 per mm at front margin.

Pedicle valve with small rounded beak; anterior slope long and moderately steep; median region slightly swollen. Brachial valve nearly flat in lateral profile but slightly concave in anterior profile. Shallow sulcus originating just posterior to mid-valve and extending to anterior margin.

MEASUREMENTS (in mm).—Holotype: length 7.6, brachial valve length 6.7, hinge width 10.7, mid-width 10.6, thickness 5.3.

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member).

LOCALITY.—USNM 702d.

DIAGNOSIS.—*Goniarina* with strongly apsacline pedicle valve interarea, flat brachial valve with shallow median sulcus.

TYPES.—Holotype: USNM 150395.

COMPARISON.—This species is larger and has flatter brachial valve than *G. futilis*, new species, and its median sulcus is deeper and wider. *Goniarina byelodes* Cooper and Grant is similar to *G. appeli* but has stronger ornament, less apsacline interarea in the pedicle valve, and less sulcate brachial valve.

DISCUSSION.—This species is named in honor of Mr. Carl Appel, owner of the Appel Ranch (Old Word Ranch), who helped us in our work.

### *Goniarina diabloensis*, new species

PLATE 39: FIGURES 1-8; PLATE 43: FIGURE 27

Large for genus, profile flatly conical, outline subrectangular; hinge widest part; sides variable, ranging from rounded to sloping medially; anterior margin broadly rounded; anterior commissure not consistently folded. Surface costellate, costellae increasing by intercalation, crowded, about 7 in 5 mm at front margin of adult.

Pedicle valve flatly triangular in lateral profile, broadly and gently convex in anterior profile. Median region distorted by attachment; lateral regions slightly swollen. Interarea short, apsacline. Cardinal extremities somewhat deflected.

Brachial valve usually somewhat distorted but with gently convex lateral profile and broadly and gently convex anterior profile. Umbonal region slightly swollen; median region usually somewhat depressed, flanks slightly convex to flattened or less commonly concave on one side. Cardinal extremities acute to rounded. Sulcus (when present) irregular; present in anterior half.

Pedicle valve interior with stout teeth and well-defined dental ridges. Myophragm small, apical. Muscle region flabellate, lightly impressed.

Brachial valve interior with small cardinalia and delicate dentifers; muscle field small with few thick radial ridges; myophragm short and anteriorly thickened in adults.

## MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| 150390a            | 21.2  | 18.4?  | 31.7                           | 29.7                         | 6.4                               | 6.3              |
| 150390b (holotype) | ?   | 16.3   | 28.7                           | 28.7                         | 0.8                               | 2.9?             |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (base).

LOCALITIES.—USNM 728f.

DIAGNOSIS.—Large shallow *Goniarina* with length about 2/3 the maximum width.

TYPES.—Holotype: USNM 150390b; figured paratypes: 150390a, k; unfigured paratypes: 150390c–j; measured paratype: 150390a.

COMPARISON.—This species differs from *G. magniextensa*, new species, in having stronger and more crowded costellae, a smaller and shorter myophragm in the pedicle valve, a narrower shell, and a more thickened adult interior.

DISCUSSION.—This is an extremely rare species, having been found only at USNM 728f. A fragment of a large *Goniarina* from USNM 728e may belong to this species, but it is not possible to be sure. Only a few specimens have been taken, four in the adult stage. The myophragm of the brachial valve varies from a narrow ridge in these specimens to a thickened club-shaped ridge in the largest specimen. The pedicle valve myophragm is a short and low ridge lodged in the apex. The pseudodeltidium is thickened by callus and partially obscures the dental ridges, especially that part of them near the apex. The interiors are only slightly thickened by callus.

*Goniarina futilis*, new species

PLATE 39: FIGURES 9–42

Small, plano- to biconvex, normally deeply conical, some specimens twisted, bent, or compressed in growth by contact with foreign objects; outline transversely semioval to subrectangular; hinge narrower than midwidth, usually not articulate; commissure regular or randomly irregular. Costellae low, rounded, weakly crenulated, increasing anteriorly by intercalation, younger costellae weaker;

costellae numbering between 14 and 22 in 5 mm on pedicle valve and between 17 and 23 on brachial valve; intertroughs shallow, rounded, about as wide as costellae; growth lines moderately prominent on pedicle valve, weak except near margins of brachial valve.

Pedicle valve deeply conical, normally with large preumbonal attachment scar; anterolateral profile normally concave, rarely convex; interarea long, flat, concave, or convex, commonly twisted or asymmetrical, forming small obtuse angle with plane of commissure; pseudodeltidium about one-third width of interarea at hinge, broadly and completely arched, without median groove or ridge; perideltidial area obscurely marked, occupying about half width of interarea.

Brachial valve slightly convex in lateral and anterior profiles; interarea becoming slightly lower near hinge ends. Sulcus poorly defined, sporadic in occurrence. Ears slightly depressed.

Pedicle valve interior with teeth projecting forward from edges of pseudodeltidial arch, converging apically as dental ridges and meeting at apex; no dental plates or septa. Muscle area in apex, shallowly excavated, muscle marks obscure. Valve floor moderately deeply striated, striae stronger near margins.

Brachial valve interior with short bifid cardinal process, each lobe projecting slightly posteriorly or ventrally from beneath the arcuate chilidium and each longitudinally grooved along posterior face; dentifers long, blade-like, bounding shallow trough-like socket and diverging into body chamber; sockets moderately deep. Muscle area occupying about half valve length, well impressed, anterior half bisected by low, sharp-crested median ridge; muscle marks bounded by longitudinal striae and broad ridges. Valve floor deeply striate near edges, weakly striate elsewhere.

## MEASUREMENTS (in mm).—

|          | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|----------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 702 |                                     |                                      |                          |                        |                             |                  |
| 150393a  | 1.6                                 | 1.6                                  | 2.3                      | 1.8                    | 1.5                         | 1.7              |
| 150393b  | 1.8                                 | 1.9                                  | 2.6                      | c.2.5                  | 1.5                         | 1.8              |
| 150393c  | 2.7                                 | 2.9                                  | 3.9                      | 3.5                    | 1.0                         | 2.2              |
| 150393d  | 2.5                                 | 2.4                                  | 4.1                      | 3.9                    | 2.7                         | 3.0              |
| 150393e  | 3.4                                 | 3.3                                  | 4.7                      | 4.4                    | 2.8                         | 3.2              |
| 150393f  | 3.9                                 | 3.7                                  | 5.0                      | 5.0                    | 4.6                         | 5.0              |
| 150393g  | 4.7                                 | 4.7                                  | 6.9                      | 5.9                    | 4.3                         | 4.8              |
| 150393h  | 5.0                                 | 5.0                                  | 7.3                      | 6.0                    | 5.0                         | 5.0              |
| 150393i  | 4.7                                 | 4.5                                  | 7.2                      | 7.1                    | 4.7                         | 5.5              |
| 150393j  | 4.9                                 | 4.7                                  | 7.0                      | 6.9                    | 4.3                         | 4.7              |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation, Cathedral Mountain Formation (*Institella* Zone), Cathedral Mountain.

LOCALITIES.—Skinner Ranch: USNM 707a; Cathedral Mountain: AMNH 500L, 500X, USNM 702, 702d, 702e, 703bs, 712o, 714w.

DIAGNOSIS.—Small *Goniarina* with proportionately large and thick cardinalia.

TYPES.—Holotype: USNM 150393j; figured paratypes: 150393c, f–i; unfigured paratypes: 150393a, b, d, e; measured paratypes: 150393a–i.

COMPARISON.—*Goniarina futilis* is distinguished by its small size, deeply conical pedicle valve with normally concave anterolateral profile, convex brachial valve, nonauriculate hinge narrower than midwidth, and well defined muscle area in the brachial valve that is bisected by a low but narrow, crested ridge only in the anterior half. It most closely resembles *G. pyelodes* Cooper and Grant from the Neal Ranch Formation, but differs in its proportionately narrower hinge, concave anterior profile, better defined muscle area with higher median ridge that only occupies the anterior half. It differs from *G. permiana* (Stehli) in its smaller size, less auriculate hinge, weaker ornamentation, concave anterolateral profile, and lack of any node on the anterior end of the median ridge of the brachial valve. This species bears little resemblance to *Schuchertella subvexa*, which is much larger, less deeply conical, more ornamented, thinner shelled, with a weakly impressed brachial muscle area.

DISCUSSION.—*Goniarina futilis* grew attached to some foreign object; many individuals attached themselves to the shells of other brachiopods or to other individuals of *G. futilis*. Many specimens in the collection from USNM 702 are cemented to-

gether in crowded clusters. Free individuals exhibit large attachment scars anterior to the beak on the pedicle valve, indicating that they too were fastened to something during growth, and most of the individuals are somewhat distorted by crowding.

*Goniarina magniextensa*, new species

PLATE 42: FIGURES 20–26

Large for genus, width approximately twice length; outline semicircular; sides rounded; hinge wide, about equal to, or slightly less than, midwidth. Anterior margin broadly rounded; anterior commissure not folded. Surface costellate, costellae of several sizes in several generations, 6 or 7 in 5 mm at front of large specimens.

Pedicle valve broadly and flatly conical with narrowly triangular lateral profile; anterior profile broadly and moderately convex. Interarea wide, short, unsymmetrical in some specimens; median and umbonal regions moderately inflated but flanks flattened.

Brachial valve gently convex in lateral profile and very broadly and gently convex in anterior profile; median region flattened; sulcus not regularly developed; posterolateral regions flattened. Interarea greatly reduced.

Pedicle valve interior with low, thick median ridge; muscle field irregularly developed. Teeth small; dental ridges reduced and hidden by callus.

Brachial valve interior with small, delicate cardinalia, equal in width to about one-sixth midwidth; muscle field small; anteromedian myophragm moderately elevated; chilidium short.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720e          |                            |                             |                  |                |                     |           |
| 150402a            | 19.6                       | 13.7                        | 30.6             | 30.6           | 7.8                 | 7.4       |
| 150402b (holotype) | ?                          | 24.7                        | 52.0             | 46.5           | 1.0                 | 4.0?      |

STRATIGRAPHIC OCCURRENCE. — Skinner Ranch Formation (Decie Ranch Member).

LOCALITIES.—USNM 705a, 720e.

DIAGNOSIS.—Wide *Goniarina* with length about half the maximum width and with small, delicate cardinalia.

TYPES.—Holotype: USNM 150402b; figured paratypes: 150402a, g; unfigured paratypes: 150402c–f, h, i; measured paratype: 150402a.

COMPARISON.—*Goniarina magniextensa* is the largest species of this genus yet found, best characterized by its great width, which is about twice the length. It differs from *G. diabloensis*, new species, in this characteristic and in having less crowded costellae, a larger and longer myophragm in the brachial valve and less thickening of the adductor region in the pedicle valve.

DISCUSSION.—The Decie Ranch Member in which *G. magniextensa* is found is noteworthy for its large number and variety of Orthotetidae. The probably turbulent water furnished an ample supply of food while the bioherms and shell clusters common at this level supplied niches in which these attached forms could maintain advantageous positions. The irregularity of the exterior of these shells, some distorted, others misshapen from living in crowded places, all testify to the fact that they must have spent a fair part of their life attached.

*Goniarina permiana* (Stehli)

PLATE 36: FIGURES 1–34; PLATE 37: FIGURES 1–27

*Schuchertella permiana* Stehli, 1954:298–299, pl. 17: figs. 19–23.

Small, plano- to biconvex, shallow to moderately deeply conical, only slightly distorted; outline transversely semiovate to subquadrate; hinge slightly narrower to slightly wider than midwidth,

commonly auriculate; commissure without consistent sinuities. Costellae moderately strong, rounded, increasing in number by intercalation, weakly crenulated, numbering 12 to 14 in 5 mm on pedicle valve, and 16 to 20 in 5 mm on brachial valve; intertroughs shallow, narrow; growth lines strong only near margins.

Pedicle valve with convex anterior profile. Interarea moderately high, slightly concave to slightly convex, occasionally twisted or bent; pseudodeltidium broadly and completely arched, without median ridge or groove; perideltidial area not visible on most specimens, about half width of interarea where visible.

Brachial valve nearly flat to slightly convex; interarea short, tapering near hinge ends. Median sulcus obscure, faintly developed on some specimens.

Pedicle valve interior with hinge teeth, converging apically as dental ridges along inside of interarea and meeting at apex. Muscle area at apex shallowly excavated; diductor scars lobate, separated by low median ridge. Valve floor weakly striated, striae deeper near margin.

Brachial valve interior with short bifid cardinal process covered at proximal end by thick arcuate chilidium, each lobe of process longitudinally grooved; dentifers often obscure, forming connection between socket plates and sides of cardinal process, elongate, bladelike, divergent, forming shallow hinge sockets beneath edge of brachial interarea. Muscle area rounded, occupying one-half to one-third valve length, anteriorly bisected by low median ridge with anterior node. Small rounded node sporadically present at posterolateral corners of muscle area, just below sockets; muscle marks faint longitudinal striae. Floor of valve weakly striated, striae stronger near margins.

## MEASUREMENTS (in mm).—

|           | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-----------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 728f |                            |                             |                  |                |                     |           |
| 150405q   | 16.0                       | 11.6                        | 20.0             | 16.3           | 7.0                 | 7.6       |
| 150405r   | 13.3                       | 9.0                         | 14.0             | 12.8           | 9.5                 | 9.6       |
| 150405s   | 11.4                       | 8.2                         | 12.8             | 11.2           | 6.0                 | 5.9       |
| 150405m   | 9.3                        | 7.7                         | 13.0             | 10.6           | 3.8                 | 4.4       |
| 150405n   | 9.1                        | 7.8                         | 12.0             | 11.7           | 4.4                 | 4.6       |
| 150405o   | 6.5                        | 5.7                         | 9.2              | 7.1            | 3.5                 | 3.6       |
| 150405p   | 6.6                        | 5.6                         | 8.4              | 8.7            | 4.2                 | 4.1       |
| 150405-l  | 5.0                        | 4.1                         | 6.3              | 5.7            | 3.0                 | 3.0       |
| 150405k   | 4.3                        | 3.9                         | 5.2              | 4.7            | 2.6                 | 2.5       |
| 150405a   | ?                          | 12.5                        | 19.2             | 14.6           | 1.1                 | flat      |
| 150405b   | ?                          | 11.7                        | 17.3             | 16.4           | 1.4                 | flat      |
| 150405c   | ?                          | 11.0                        | 16.4             | 14.0           | 1.1                 | flat      |
| 150405d   | ?                          | 9.4                         | 15.1             | 16.5           | 0.7                 | flat      |
| 150405e   | ?                          | 9.2                         | 14.1             | 13.6           | 1.0                 | flat      |
| 150405f   | ?                          | 9.8                         | 15.0             | 13.3           | 1.2                 | 1.9       |
| 150405g   | ?                          | 8.7                         | 12.8             | 11.0           | 1.1                 | 2.2       |
| 150405h   | ?                          | 7.4                         | 9.4              | 11.3           | 0.6                 | flat      |
| 150405i   | ?                          | 5.7                         | 9.5              | 9.2            | ?                   | flat      |
| 150405j   | ?                          | 4.5                         | 6.9              | 6.8            | ?                   | flat      |
| 150405t   | 11.5                       | 8.4                         | 12.5             | 12.6           | 7.4                 | 9.1       |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (base).

LOCALITIES.—AMNH 625, 628, 629, 631, 696; USNM 725c, 728e, 728f, 728h, 745.

DIAGNOSIS.—Medium sized, strongly conical *Goniarrina* with cardinalia width one-fourth the shell width.

TYPES.—Figured hypotypes: USNM 150405a, q, t, 153514a-m, 153515a-f, 153516; measured hypotypes: 150405a-t.

COMPARISON.—*Goniarrina permiana* is characterized by its rather large size, relatively strong costellation, cup-shaped pedicle valve with convex anterior profile, and flattish brachial valve with a well-defined muscle area that is anteriorly bisected by a low median ridge that terminates anteriorly in a node. It differs from *G. pyelodes*, the type-species, and *G. futilis*, new species, in its larger size, lower interarea, and nodose brachial median ridge. It differs from *Schuchertella subvexa* in its stronger and thicker shell, weaker costellation, proportionately narrower hinge, lower pedicle interarea, which does not project so strongly backward, and by its well-defined brachial muscle area with nodose median ridge.

DISCUSSION.—Stehli (1954:299) discussed possible mode of growth of *G. permiana*. Small attachment

scars and minimum of distortion of the shells indicate that the species did not form closely crowded clusters, but more probably "did not habitually grow where there was excessive competition for space . . . It is believed that the species may have lived near the reefs, but not in the zones of strongest wave action."

*Goniarrina pyelodes* Cooper and Grant

PLATE 38: FIGURES 1-39

*Goniarrina pyelodes* Cooper and Grant, 1969:2, pl. 4: figs. 26-30.

Shell small, biconvex, shallow to deeply conical, normally slightly twisted or bent, but not usually severely distorted; outline transversely semiovate to subquadrate; hinge wide, slightly narrower than maximum width of shell, normally slightly auriculate; anterior commissure regular, without consistent sinuosities. Fascicostellate, costellae low, rounded, weakly crenulated on some shells, increasing in number anteriorly by intercalation, younger costellae weaker, between 15 and 22 on pedicle valve in 5 mm, between 18 and 24 on the brachial valve; intertroughs narrow, rounded; growth lines faint to invisible except near margins.



Pedicle valve shallowly to deeply conical, normally with attachment scar sharp or blunt near apex; anterolateral profile normally convex, rarely concave; interarea long, wide, nearly flat, asymmetrical or twisted, meeting plane of commissure at right or small obtuse angle; pseudodeltidium about one-third as wide as interarea at hinge, broadly and completely arched, without median groove or ridge; perideltidial area obscurely marked, occupying more than half width of interarea.

Brachial valve moderately convex; interarea very low, becoming lower toward hinge ends.

Pedicle valve interior with hinge teeth extending apically as convergent dental ridges, meeting at apex of valve; no plates or septa. Muscle area not visibly delimited; no muscle marks visible. Floor

of valve weakly striated, striae stronger near margins.

Brachial valve interior with very short, bifid cardinal process, each lobe longitudinally grooved and projecting slightly from beneath arcuate chilidium; dentifers rudimentary, nearly buried in callus, fused to sides of cardinal process, long, divergent, troughlike, producing moderately deep hinge sockets at attached end, free ends projecting into body chamber, supported by adventitious shell. Muscle area weakly impressed about half as long as valve, bisected longitudinally by low median ridge; muscle marks weak, consisting of longitudinal troughs and ridges. Floor of valve weakly striated, striae stronger near margins.

MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| USNM 701k          |   |  |                                |                              |                                   |                  |
| 150411a            | 30.   | 2.0  | 2.9                            | 2.6                          | 1.6                               | 2.5              |
| 150411b            | 3.7   | 3.3  | 4.4                            | 3.4                          | 1.3                               | 1.8              |
| 150411c            | 4.7   | 4.0  | 5.8                            | 5.0                          | 2.5                               | 3.5              |
| 150411d            | 5.0   | 4.3  | 6.0                            | 5.3                          | 3.0                               | 3.9              |
| 150411e            | 5.5   | 5.2  | 7.5                            | 6.6                          | 2.0                               | 2.9              |
| 150411f            | 7.2   | 5.3  | 7.8                            | 6.9                          | 2.5                               | 4.0              |
| 150411g (holotype) | 7.6   | 5.9  | 8.4                            | 7.1                          | 4.3                               | 5.6              |
| 150411h            | 9.0   | ?  | 10.4                           | 9.1                          | 5.5                               | 5.0              |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 9–14).

LOCALITIES.—USNM 701a<sup>3</sup>, 701k.

DIAGNOSIS.—Small, strongly fascicostellate *Goniarrina*.

TYPES.—Holotype: USNM 150411g; figured paratypes: 150411d, f, i–n; unfigured paratypes: 150410, 150411a–c, e, h; measured hypotypes: 150411a–h.

COMPARISON.—*Goniarrina pyelodes* is characterized by its small average and maximum size, wide and normally auriculate hinge, interarea that meets the plane of commissure near a right angle, normally convex anterolateral profile of the pedicle valve, and low, weakly crenulate fasciculate costellae that are relatively closely crowded. It differs from *Schuchertella subvexa*, which also occurs in the Neal Ranch Formation, primarily in its smaller size, thicker shell wall, more strongly convex brachial valve, auriculate hinge, and less posteriorly projecting pedicle beak. Interiorly, its dentifers are longer and more protruding, and its brachial mus-

cle area more definitely circumscribed. This species differs from *G. futilis*, which also is small, but it is shallower, with a more cup-shaped pedicle valve, a convex rather than concave anterolateral profile, a more frequently auriculate and proportionately shorter hinge, and less strongly marked brachial muscle area. *Goniarrina permiana* (Stehli) is similar, but it attains larger size, is more strongly ornamented, and has a strong median node near the anterior edge of the brachial muscle area.

DISCUSSION.—*Goniarrina pyelodes* is not strongly deformed by closely crowded growth, and the collection contains no clusters, only individual shells. The attachment scars on most shells are larger and deeper than on *Schuchertella subvexa* and the shells thicker, perhaps indicating that *G. pyelodes* lived where currents were stronger and firmer attachment was necessary. *Goniarrina futilis*, on the other hand, grew in clusters, with crowded conditions producing more deformed shells.

*Goniarina striata*, new species

PLATE 40: FIGURES 2-25

Small, wider than long, pedicle valve subconical, interarea long, ranging from procline to strongly apsacline. Sides rounded; hinge wide, usually forming obtuse cardinal extremities. Anterior margin broadly rounded. Maximum width at midlength. Anterior commissure without consistent folding. Surface costellate, the costellae somewhat distant, measuring 3 or 4 per mm on average specimens.

Brachial valve moderately convex in lateral profile, forming triangular outline with palintrope. Umbonal and median regions with marks of at-

tachment. Umbonal region moderately swollen; anterior region flattened. Anterolateral slopes steep. Interarea fairly long, pseudodeltidium moderately arched.

Brachial valve variable in lateral profile from flat to gently convex; cardinal extremities flattened; median region slightly swollen; flanks flattened.

Pedicle valve interior without trace of muscle impressions and without apical myophragm.

Brachial valve interior with broad and flat dentifers strongly elevated and defining deep sockets. Hinge with obscure teeth and sockets. Muscle area small with fine radial lines along the anterior border. Myophragm irregularly developed.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720d          |                            |                             |                  |                |                     |           |
| 150415a            | 9.0                        | 5.8                         | 9.6              | 9.2            | 4.0                 | 4.2       |
| 150415b            | 6.4                        | 4.1?                        | 7.0              | 6.7            | 4.6                 | 4.1       |
| 150415c            | 6.5                        | 4.1                         | 6.7              | 5.8            | 3.8                 | 3.6       |
| 150415d            | ?                          | 7.1                         | 9.8              | 8.7            | 1.7                 | 2.1?      |
| 150415e            | ?                          | 6.1                         | 9.1              | 8.6            | 0.8                 | 1.2       |
| 150415f            | ?                          | 5.4                         | 8.2              | 6.8            | 0.8                 | ?         |
| USNM 721j          |                            |                             |                  |                |                     |           |
| 150417a            | 9.5                        | 8.2                         | 13.8             | 13.2           | 5.2                 | 4.8       |
| 150417b            | 5.0                        | 4.2                         | 6.8              | 6.0            | 3.6                 | 3.4       |
| 150417c            | ?                          | 6.8                         | 9.8              | 7.5            | 0.4                 | ?         |
| 153550a (holotype) | 4.8                        | 4.7                         | 6.6              | 6.3            | 3.0                 | 3.0       |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 710u, 720d, 721j, 721z, 724b, 726e.

DIAGNOSIS.—Small, transverse, with broad-bladed dentifers.

TYPES.—Holotype: USNM 153550a; figured paratypes: 150413, 150415c, e, 150417a, 153551a-d; unfigured paratypes: 150415a, b, d, f; 150417a, c; measured paratypes: 150415a-f, 150417a-c.

COMPARISON.—The specimens of this species are variable and difficult to compare with other forms also having considerable variability. This species suggests the two small species: *G. futilis* and *G. pyelodes*. It differs in having less regularly developed costellae, more delicate cardinalia, and a more modest development of the myophragm.

DISCUSSION.—The specimens of *Goniarina striata*, like many others from USNM 720d are coated, inside and out, by an amorphous material that may

have originally been an algal coating, now preserved in siliceous form. Fortunately some of the specimens were not completely covered and one side or the other can be obtained fairly clean and the structures seen. At USNM 721j a few specimens of *Goniarina* are generally larger but thinner shelled. Their dimensions conform with those from USNM 720d, but the interior details of the brachial valves are not the same; however, the two are tentatively given the same name.

*Goniarina* species

Several specimens of *Goniarina* of fairly large size are not referable to any of the species described above. These are represented mostly by brachial valves and are noted below.

*Goniarina* SPECIES 1 (Plate 41: figures 18, 19).—This is represented by several specimens, all but one of them in a youthful or juvenile condition.

The one adult is a large brachial valve 15.1 mm long, 27.4 mm at midwidth, which is the widest part, the hinge 23.8 mm and the thickness 3.7 mm. It is, thus, gently convex in both profiles and fairly inflated in midvalve. The costellae are unequal in size, larger ones setting off groups of smaller ones, presenting an ornamentation like that of some Mississippian species of *Schellwienella*. The cardinalia are unusually narrow and the muscle region longitudinally slightly elliptical. The myophragm is slender, but an elevated ridge, not extending anterior to the anterior margin of the muscle field, bounds each side of the field just anterior to the end of the dentifer. This valve has details not seen in other of the large *Goniarinas*. This specimen comes from USNM 708u at the base of the Cathedral Mountain Formation.

Figured specimen: USNM 150420.

*Goniarina* SPECIES 2 (Plate 93: figures 1, 2).—Two not fully grown brachial valves and one juvenile pedicle valve. The brachial valves are like the above in ornament, but the cardinalia are not narrowly bowed; instead, they are spread out. The specimens are from the Cathedral Mountain Formation (*Institella* zone) at USNM 702b and 703b.

Figured specimen: USNM 150421a.

*Goniarina* SPECIES 3 (Plate 42: figures 9–14; Plate 42: figures 17–19).—The lot (USNM 150423) consists of four fragmentary specimens, one part of a pedicle valve, the other a nearly complete brachial valve. The pedicle valve has a length of about 17 mm and a width of 26 mm. The interarea is short and the pseudodeltidium flatly convex. The ornament consists of thin costellae, the larger ones setting off groups of one to three which are intercalated. No details of the interior can be ascertained. The brachial valve is about 18 mm long and has a midwidth of 35.6 mm. The hinge is 33 mm wide. The shell is somewhat distorted, but normally it would be nearly flat. The cardinalia are wide and thick. The adductor field is small, but its margin is considerably thickened laterally. The myophragm rises to a crest anteriorly and is thick and strong. The species is from the Road Canyon Formation at USNM 722–1.

Figured specimens: USNM 153513a, b, 150423a.

*Goniarina* SPECIES 4.—A specimen with both valves measuring 24 mm at the hinge and 17 mm long is strongly apsacline and has a large convex

pseudodeltidium. The brachial valve is nearly flat. The specimen is unsilicified and comes from the *Uddenites*-bearing Shale Member at USNM 701x.

Mentioned specimen: USNM 155126.

*Goniarina* SPECIES 5 (Plate 41: figures 1–17; Plate 94: figure 19).—Reminiscent of *G. magniextensa*. Two growth forms are included here, but the extended form may not be characteristic of the species because several other specimens are not nearly as wide. The lot (USNM 152562) consists of 12 specimens in various states of fragmentation except for one perfect valve. Since three are immature pedicle valves, no clear view of the species can be obtained. In the best specimen, the brachial valve is about 35 mm wide at the hinge but only 15 mm long. Another specimen (based on the half measure) is 30 mm wide by 19 mm long. The cardinalia of both specimens are delicate and rather narrow. The median ridge is moderately long and well developed. The best pedicle valve is 14 mm wide by 11 mm long and is fairly long. The interarea is flat with a slightly arched pseudodeltidium. The exterior is ornamented by costellae of two sizes, the stronger costellae separate groups of 1, 2, or 3 finer costellae. Four of the larger costellae appear in 5 mm at the anterior margin. These specimens were recovered from the silty limestone of the Cathedral Mountain Formation of USNM 721u and may be related to, if not the same as, *Goniarina* species 3.

Figured specimens: USNM 153549, 152562a–i.

*Goniarina* SPECIES 6 (Plate 43: figures 3–26).—Several specimens indicate a species of large size, but no adult pedicle valves have been taken. Three immature pedicle valves have a prominent and somewhat twisted umbonal region and long interarea with strongly convex pseudodeltidium. The brachial valves are almost flat with wide hinge but narrower than maximum width, which is near midvalve. The sides are rounded and the anterior margin broadly curved. The largest specimen measures 24 mm in length by 40 mm at midvalve. The specimens come from the Neal Ranch Formation (bed 4) at USNM 727e.

Figured specimens: USNM 153541a–f.

*Goniarina* SPECIES 7 (Plate 42: figures 6–8; Plate 93: figure 3).—This is a medium-sized species represented by 14 specimens (USNM 152564); only one of them is adult and only two of them pedicle

valves. The largest specimen is nearly perfect and is 18 mm wide by 12 mm long. The valve is subrectangular in outline with the cardinal extremities nearly a right angle. The cardinalia are short and wide, fairly strongly bowed. The median ridge is short and a callosity appears just anterior to the brachioophores. The cardinalia, median ridge, and callosities are thick and exaggerated in one of the juveniles. The pedicle valve conforms in outline to the brachial. The interarea is apsacline and fairly long, but the pseudodeltidium is not strongly elevated.

This species is smaller and has a different outline than *Goniarina* species 5 and *G. magniextensa*. Good pedicle valves are needed to define all of the above species, but they appear to be rare in adult form. The specimens are from the Road Canyon Formation at USNM 726x.

Figured specimen: USNM 153511a, 152564a.

#### HYPOPSIINAE, new subfamily

Schuchertellidae having a spondylium in young forms, the spondylium becoming sessile in adult and old individuals.

*Hypopsia* is at present the only genus known in this subfamily.

#### *Hypopsia*, new genus

[Greek *hypopsia* (suspicion)]

Biconvex or nearly planoconvex, shallow to deeply conical; outline transversely semioval to subquadrate; hinge width nearly equal to midwidth. Costellae moderately strong, rounded to sharp, increasing anteriorly by intercalation, intertroughs shallow, rounded; growth lines covering shell, producing light crenulation of costellae and intertroughs, irregularly spaced stronger growth lines more frequent near margins.

Pedicle valve shallow to deeply conical; lateral profile gently convex to slightly concave, interarea wide, high, convex, or concave; perideltidial area lightly marked; pseudodeltidium completely but gently arched.

Brachial valve moderately convex to nearly flat; chilidium wide, arcuate; interarea definite but low, tapering toward hinge ends.

Pedicle valve interior with strong teeth project-

ing forward at sides of pseudodeltidium, extending apically as convergent dental ridges along underside of interarea, meeting at apex of valve, normally buried in callus for most of length; strong dental plates extending from each dental ridge, meeting above floor of juvenile valves, forming spondylium and median septum, meeting at floor in larger individuals, and reaching floor without meeting in largest specimens; above sequence preserved in mature individuals, continuous from apex to anterior end of spondylium. Muscle marks within spondylium.

Brachial valve interior with very short, wide cardinal process, two short lobes protruding from cover of chilidium, each grooved along posterior edge; prominent median ridge along underside of process; sockets formed by long, divergent dentifers and a proximal thickening; sockets reinforced by shell deposited on their inner surfaces and anterior. Muscle area in umbonal arch, occupying up to half valve length.

TYPE-SPECIES.—*Hypopsia versuta*, new species.

DIAGNOSIS.—Schuchertellidae with spondylium.

COMPARISON.—*Hypopsia* is characterized by its peculiar spondylium, which descends toward the floor of the pedicle valve as the valve becomes larger, which is progressively filled with shell material at the posterior and which maintains the spondylium floor at shallow depth. The wide but short cardinal process is another distinctive feature, necessitating a rather wide pseudodeltidial arch.

This genus combines features of several genera. The cardinal process and completely arched pseudodeltidium most closely resemble those of *Schuchertella* or *Derbyoides*. The moderately deeply conical pedicle valve is more characteristic of *Derbyia* and *Ombonia*; however, it closely resembles the shape of some *Goniarina* that occur in the Glass Mountains Permian.

The spondylium is the most characteristic feature of *Hypopsia*. In young specimens or near the apex of an older one it is Y-shaped, as in *Ombonia* or *Geyerella*, with a rather high median septum. A section across the pedicle beak near the apex would show this type of spondylium, and, being unPLICATED, the shell might easily be mistaken for a representative of some species of *Ombonia*. A section farther from the pedicle beak, cutting the spondylium near its middle, would produce a V- or U-

shaped cross section, and the specimen might be erroneously assigned to a species of *Sicelia*. A section that cut the spondylium near its anterior end would show dental plates that intersect the floor of the valve without meeting, as in *Sicelia*.

This genus is without analogue among the Schuchertellidae. Its resemblance to *Ombonia* at one stage of growth and to *Sicelia* at another is superficial at best: neither of those genera has the widely arched pseudodeltidium of *Hypopsia*, and both have long, narrower cardinal processes more characteristic of *Meekella* or *Derbyia*. In addition, both *Ombonia* and *Sicelia* are typically more conical, the hinge narrower, the perideltidium more strongly marked, and the interarea more normally concave than convex as in *Hypopsia*. The spondylium of *Hypopsia* appears to be similar to that of *Orthotetella* if the median septum were fully developed and the chamber of the spondylium reduced by filling at the apex.

The cardinal process is very small and laterally spread like that of *Schuchertella*. The chilidium is entire, rather than bilobed, as in many genera such as *Derbyia* and *Ombonia*. This also accounts for the fact that the pseudodeltidium neither bears a monticulus nor does it have a groove.

### *Hypopsia versuta*, new species

PLATE 31: FIGURES 1-21; PLATE 32: FIGURES 6-19;

PLATE 43: FIGURE 1

Moderately large, biconvex, shallow to deeply conical; shell wall thick; outline transversely semi-ovate to subquadrate; hinge wide, about equal to midwidth; anterior commissure rectimarginate to weakly uniplicate. Costellae moderately strong, rounded to rather sharp, weakly crenulate, closely spaced and with narrow intertroughs, numbering between 10 and 18 in 5 mm on pedicle valve, averaging about 14, slightly more crowded on brachial valve, averaging about 15 in 5 mm; growth lines light, closely crowded, forming transverse crenula-

tion of costellae and intertroughs, stronger growth laminae widely spaced over shell, more closely spaced near margins.

Pedicle valve shallow to deeply conical; lateral profile gently convex to gently concave, flexed in some species; interarea wide, normally long, commonly convex, rarely concave, slightly twisted or otherwise asymmetrical in some specimens; perideltidial area lightly marked, about half width of interarea; pseudodeltidium moderately wide, completely arched, without median ridge or groove.

Brachial valve flatly convex; interarea low, tapering toward hinge ends; chilidium broad, arched to conform to pseudodeltidium.

Pedicle valve interior with strong teeth extending apically as convergent dental ridges, meeting at apex of valve, normally buried for most of length by material of spondylium; dental plates strong, thick, extending from dental ridges to converge toward valve floor, meeting above floor and joining a median septum in juvenile valves and near apex of mature valves, meeting at floor of more mature valves and about midway in still older valves, not meeting but intersecting floor at anterior end of spondylium in largest valves; spondylium shallow, progressively posteriorly filled by shell material with growth, maintaining nearly constant depth of spondylium. Floor of valve anterior to muscle area weakly to moderately strongly striated, striae stronger near margins.

Brachial valve interior with short, wide, bifid cardinal process, each lobe projecting from beneath chilidium and grooved longitudinally; median ridge on underside of process prominent, but extending into umbonal arch; dentifers divergent, protuberant, fused with cardinal process to form sides of shallow sockets. Muscle area in umbonal arch, occupying one-third to nearly one-half valve length; bilobed, with very low median ridge terminating at anterior end in slight swelling; muscle marks consisting of weak longitudinal striae in muscle area. Floor of valve weakly striated, striae stronger near margins.



## MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| 152587e            | 20.3  | ?  | 22.1                           | 19.3                         | 9.0                               | 7.6              |
| 152587d            | 21.8  | ?  | 26.0                           | 23.5                         | 11.5                              | 10.0             |
| 152587c            | 30.0  | ?  | 27.3                           | 23.9                         | 15.7                              | 13.5?            |
| 152587b            | 24.9  | ?  | 28.5                           | 25.0                         | 12.0+                             | 10.5             |
| 152587a            | 39.3  | ?  | 37.7                           | 34.4                         | 17.9                              | 16.0             |
| 152587f            | ?   | 23.0   | 34.8                           | 32.8                         | ?                                 | 4.8              |
| 152587g            | ?   | 11.2   | 15.7                           | 12.3                         | ?                                 | 2.0              |
| 152587h            | 7.8   | ?  | 9.6                            | 10.0                         | 5.8                               | 5.6              |
| 152587i (holotype) | 12.0  | 10.5   | 14.0                           | 13.0                         | 10.0                              | 10.7             |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of Bed 2 of P. B. King).

LOCALITY.—USNM 701.

DIAGNOSIS.—*Hypopsia* with variable spondylium.

TYPES.—Holotype: USNM 152587i; figured paratypes: 152587a–f, j–n; measured paratypes: 152587a–h; unfigured paratypes: 152587g, h, o–v.

COMPARISON.—This is the only known species of the genus.

DISCUSSION.—The specimens of this species are not well silicified, which is unfortunate when one considers the unique characters of the genus. The shell was extremely thick and gross and the silicification is largely superficial. Any crack in the silicification, therefore, let the acid attack the thick secondary deposits of the interior. The result is that some of the specimens are ragged, and in others the interareas are badly preserved. This species is very rare and has been taken from one place only, although it has been sought elsewhere in the mountains.

### DIPLANINAE, new subfamily

Schuchertellidae having large interareas on both valves, cardinal process with short shaft and bifurcated myophore; dentifers nearly obsolete, seldom visible; sockets cuplike.

The only genus in West Texas is *Diplanus* Stehli.

This subfamily has been set apart from its fellows in the Schuchertellidae because of the advanced character of the cardinal process, which shows a tendency toward that of the Derbyiidae in the elongation of the shaft and the bifurcation of the myophore. Unlike *Orthotetella*, which has a conservative cardinal process, no erismata are de-

veloped. The anterior end of the sockets in *Diplanus* are closed by thick shell deposits that answer to G. A. Thomas' definition of socket plates. These are secondary deposits. *Diplanus* seems to be a terminal genus because we have not seen any other genera quite like it or which might have been derived from it.

In the youngest brachial valves of *Diplanus* seen, measuring about 2.5 mm in width, the cardinal process is like that of *Schuchertella*, bilobed rather than bifurcated, and the dentifer (brachiophore) is a flat blade. As growth continues, the cardinal process elongates and the dentifer is completely covered laterally on both sides and is also added to on its edge. It cannot be identified as a discrete plate in the adult.

### Genus *Diplanus* Stehli, 1954

*Diplanus* Stehli 1954:299.

Small with elongate conical valve and convex brachial valve; hinge straight, usually without ears; interareas on both valves, that of brachial valve unusually well developed. Anterior commissure usually not folded unless the valves are distorted. Attachment surface usually large and frequently occupying most of the ventral surface. Valves costellate and lamellose, costellae narrow and elevated and prolonged into small spines on some lamellae.

Pedicle valve with broad interarea and strongly arched prominent pseudodeltidium; perideltidial area not observed. Teeth large and protruding; dental ridges thick; delthyrial chamber narrow; no septum or myophragm. Musculature obscure.

Brachial valve with broad interarea, wide chlidium usually medially grooved. Cardinal process

at high angle to hinge, forked and elongated; socket plates broad, anteriorly narrowly rounded and occasionally with trace of dentifer process; sockets deep, bounded laterally by a thick ridge; adductor field broad and rounded; myophragm rare.

TYPE-SPECIES.—*Streptorhynchus lamellatum* R. E. King (1931:49, pl. 4: figs. 1a–c only).

DIAGNOSIS.—Schuchertellidae with a broad interarea on the brachial valve.

COMPARISON.—*Diplanus* is obviously externally similar to *Streptorhynchus*, from which it differs in the strongly lamellose ornament and well-developed interarea on the brachial valve.

*Diplanus* is a distinctive and easily recognized brachiopod, but it is so variable that it is difficult to identify species within it. The distinction between species is not difficult in adult forms, but the young with distortion resulting from attachment and crowding and the variability of the ornament make problems in recognition. The attachment surface may be confined to the umbonal region, or it may take a generous share of the ventral surface. The positioning of the embryo after it has settled and the nature of the attachment surface are factors in determining the ultimate shape of the shell. Specimens on broad, flat surfaces tend toward roundness and flatness, but ones attached in confined spaces may undergo considerable distortion.

The most important distinguishing feature of this genus and the one that gives its name is the interarea on each valve. The brachial interarea is better developed in this genus than in other schuchertellids. Another feature is the lamellate character of the interareas. This is shown in most of the Glass Mountains specimens, but it may be an exaggeration owing to the silicification. Specimens of *Diplanus* from the lower Bone Spring Formation in the Sierra Diablo generally have the interarea smooth. The lamellose character appears on both valves and is shared by the chilidium as well as by the interarea. The brachial valve interarea is shorter than the pedicle valve interarea and is variable. In large and old specimens, it is generally prominent and is nearly plane to concave. The chilidium is broad and rises above the interarea increasingly toward the pedicle valve, where it is inserted under the margin of the pseudodeltidium. Medially the chilidium is marked by a

depression representing the position of the gap between the lobes of the cardinal process. Behind the chilidium, between it and the umbo, is a groove and abrupt change in direction of the interarea. This portion represents the earliest part in the development of the structure.

An odd feature of *Diplanus* is the lack of a perideltidial area, a feature that is common in many orthotetaceans. No trace of this structure can be seen on the exterior in the best-preserved specimens, nor can any trace be seen in decorticated or damaged specimens. The feature seems not to have been developed in this genus.

The ornament of *Diplanus* is very distinctive and consists of costellae and strong lamellae. The shell grows by increments inside the margin, leaving the preceding shell layer overhanging the new shell. This also leads to development of a ragged or falsely spiny appearance. The shell is costellate, the costellae alternating in size, the new ones being intercalated at the anterior of the shell. Some costellae are continued anteriorly slightly beyond the margin of the shell and thus appear as interiorly grooved processes. When slightly curved away from the margin, they have the appearance of blunt or truncated spines. No definite pattern of intercalation of costellae was detected; in some specimens new ribs appear as single costellae between the larger ones; in others a pair of costellae are intercalated. In some young specimens the costellae remain nearly the same size until near maturity. These small differences create a variety of types living together, presumably all of the same species. Another variable feature is the anterior widening of the costellae, which produces another variable element in the ornament. One large specimen of *D. catatonus* from the Neal Ranch Formation shows a large band of fine costellae at the anterior, the intercalation having gradually eliminated the coarser costellae.

The interior of the pedicle valve does not offer any structural novelties, but it is noteworthy for the large size of the teeth. These are thick and long, somewhat crescentic in cross section, and inclined with the convex surface toward the sides. The palintrope and the pseudodeltidium form a shelf over them. Some slight longitudinal striation is visible in large specimens. The delthyrial chamber commonly is thickened considerably, and the pos-

terior ends of the dental ridges thus buried, but, in spite of this thickening, well-defined muscle marks were not differentiated, and a myophragm appears not to have been developed.

Like most other structural features of this genus, the cardinalia are variable in length, thickness, and their angular relation to the hinge or plane of commissure. The structures are welded into a solid piece in which some of the parts are clearly visible but others not. The myophore, unlike that of most schuchertellids, consists of two elongate lobes grooved distally on the posterior face. The lobes in some specimens are short, but in others they extend for a considerable distance into the opposite valve. In some specimens the lobes are welded together but in others, more rarely, the lobes are separate but subparallel. Posteriorly the lobes are further cemented by the chilidium that overlies them and bears a median indentation corresponding to the depression dividing the myophore lobes. The inner wall of the socket is joined to the anterolateral face of the myophore, descends obliquely anteriorly, and is abruptly curved to form the deep socket. The socket is bounded on the outside by a thick ridge, and the areas outside this ridge are concave. The structure is reminiscent of that of *Derbyoides*, *Goniarina*, and *Tropidelasma*. At the anterolateral extremity of the socket wall mentioned, a small nub appears in some of the better preserved specimens. This is the only trace of a brachiophore or dentifer seen in the genus. These nubs are very small and must be regarded as vestigial. Supporting plates surrounding the muscle field do not appear in this genus because the cardinalia are greatly confined. The muscle field is not well preserved in any of the silicified specimens, but a delicate, short myophragm anterior to the cardinalia appears in well-preserved specimens. This is a threadlike ridge that scarcely attains midvalve.

*Diplanus* has been found in the Glass Mountains in rocks ranging in age from Upper Pennsylvanian (Gaptank) into Leonardian (Cathedral Mountain). The species are similar, but they show at least one consistent developmental trend that may be used to distinguish them. This involves the width of the pseudodeltidium relative to the total width of hinge. In these attached forms, gross shape of the shell is variable and, therefore, nearly useless for

distinction of species. Ornamentation is quite similar among the species, with only subtle differences that require large collections in order to be distinguished. Useful and consistent group distinctions have been determined only in features of the pedicle interarea and pseudodeltidium. In general, the narrowest pseudodeltidia are in Pennsylvanian specimens, and the widest in Leonardian specimens. To some extent, this is a function of width of hinge relative to total width of shell, but this parameter alone would not distinguish the Pennsylvanian from the Leonardian species.

Stehli (1954:300) states his belief that *Diplanus* is known only from West Texas; however, a species belonging to this genus was described from the *Schwagerina* limestone of the Sosio Valley in Sicily under the name *Canavaria sinuata* Merla (1928:76, pl. 2: figs. 5-7). Greco (1938:5, 14) referred "*C.*" *sinuata* to *Streptorhynchus*, considering it to be generically distinct from the other two species that made up "*Canavaria*" (later changed to *Gemmelaria* Ruiz, 1933:20, then to *Sicelia*, Merla, 1934:284). Both of these authors (Merla, 1928:77; Greco, 1938:14, 1942:137) emphasized in their descriptions of "*C.*" *sinuata* the unusual development of the brachial valve interarea. Merla's photographs (pl. 1: figs. 5-7) do not show this feature clearly because of the angle from which they were taken, but Greco's photographs (1938, pl. 1: figs. 1-8; 1942, pl. 13: figs. 1-3) illustrate it very well. Presence of a well-developed brachial valve interarea, as well as details of ornamentation that are visible in Greco's photographs, leave little room for doubt that the species should be *Diplanus sinuatus* (Merla). This species was not the type-species of "*Canavaria*", and it is not congeneric with species of *Sicelia* as now constituted.

### *Diplanus apochordus*, new species

PLATE 44: FIGURES 26-40

Large, irregularly conical, outline elongate oval, brachial valve strongly convex, nearly conical in large individuals, hinge line slightly narrower than widest part. Pedicle interarea long, triangular, flat, concave, convex or twisted, bisected by narrow pseudodeltidium.

Brachial valve interarea long for genus, normally concave and overhanging hinge. Shell thick, orna-

mented by strong circum-umbonal laminations with weak, distant radial costellae, ornament similar on both valves.

Pedicle valve interior a deep cone, devoid of septa; hinge teeth thick and bluntly conical, projecting from underside of palintrope, continuing as thick ridges along sides of delthyrial cavity.

Brachial valve interior deeply concave, with strong bifid cardinal process supported by fusion of dentifers to it; sockets deep, outlined by sides of cardinal process and socket plates. Muscle field occupying about one-third valve length, commonly bisected by low myophragm.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| 150440a            | 19.5?                      | 20.7                        | 19.1             | 15.0           | 15.0                | 24.8      |
| 150440b (holotype) | 20.6                       | 17.4                        | 17.8             | 11.4           | 10.3                | 16.0      |
| 150440c            | 11.5                       | 11.5                        | 11.6             | 8.5            | 8.5                 | 15.6      |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member).

LOCALITY.—USNM 707a.

DIAGNOSIS.—Large and elongate *Diplanus* with highly arched umbonal region in the brachial valve.

TYPES.—Holotype: USNM 150440b; figured paratypes: 150440a, c; unfigured paratypes: 150440a, c; unfigured paratypes: 150440d–e; measured paratypes: 150440a, c.

COMPARISON.—This species is distinguished from all others in the Glass Mountains by its large size, the elongated pedicle valve, and the strongly arched umbonal region of the brachial valve.

DISCUSSION.—The strongly arched umbonal region of the brachial valve of this species, especially when seen in lateral profile, is very striking. No other species is so constituted, but some specimens of *D. catatonus*, new species, approach it in late adulthood or in obese specimens. Usually these can be readily distinguished because they are shorter than the Decie Ranch specimens.

It might be suggested that the specimens of *D. apochordus* represent obese forms, but this appears not to be so because the species is represented by a fair range in size. The smallest specimen shows the strong swelling of the brachial valve umbo.

*Diplanus catatonus*, new species

PLATE 44: FIGURES 1–24; PLATE 45: FIGURES 1–21; PLATE 46: FIGURES 1–24; PLATE 49: FIGURES 13–30; PLATE 50: FIGURE 46

*Streptorhynchus lamellatum* R. E. King (part), 1931:49, pl. 4: fig. 3.

Shell conical, deep or shallow, regular or distorted, normally with attachment near apex or along anterior slope of pedicle valve; outline nearly circular, or subquadrangular, widest near midline of nearly flat to strongly convex brachial valve, some shells slightly constricted on one or both sides immediately anterior to hinge, producing slight alation. Pedicle interarea long, broad, triangular, flat, concave, convex, or twisted to left or right, bisected from apex to narrow, outwardly convex pseudodeltidium that occupies less than one-third of total width of hinge and is narrower than one side of interarea; hinge straight, invariably narrower than maximum shell width.

Brachial valve interarea short, decreasing laterally, flat or slightly concave, continuing plane of pedicle interarea or overhanging, divided by strongly laminated convex chilidium, slightly wider than pseudodeltidium, produced by posterior growth of cardinal process. Shell thick, with strong circum-umbonal laminae; brachial valve with peculiar square-ended and posteriorly dimpled umbo, and ornamented by strong costae, added by intercalation, more or less sharply discontinuous, being broken at edge of each lamina, but continuing on successive laminae, some slightly recurved at edges of laminae, giving spiked appearance to valve. Costation of pedicle valve similar, but normally weaker, absent along surfaces where valve attached or adjoined neighboring shells.

Pedicle valve interior deep or shallow irregular cone, flat along hinge line, devoid of septa or plates. Hinge teeth bluntly conical, projecting dorsally from beneath palintrope forming supporting ridges



on underside of interarea that converge toward beak, along sides of arched cavity beneath pseudodeltidium.

Brachial valve interior semicircular to subquad-rangular in outline, slightly alate on one side or both; hinge line straight. Cardinal process large, strong, supported by convergent and posteriorly flexed dentifers fused to anterior side; process bifid,

and either or both of the two lobes may be bifid; growth producing a posterior groove along length of process. Hinge sockets deep, close against cardinal process, outlined by sides of process and fused dentifers. Muscle field roughly same shape as valve, extending forward about one-third valve length bisected by low median ridge in some specimens.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701d          |                            |                             |                  |                |                     |           |
| 150432a (holotype) | 19.3                       | 16.3                        | 17.3             | 15.7           | 11.6                | 19.8      |
| 100432b            | 18.0                       | 16.4                        | 15.0             | 11.0           | 11.8                | 18.0      |
| 150432c            | 15.1                       | 12.2                        | 16.3             | 15.9           | 9.2                 | 12.3      |
| 150432d            | 12.8                       | 11.2                        | 13.4             | 9.8            | 5.8                 | 10.0      |
| 150432e            | 11.6                       | 11.0                        | 12.0             | 8.0            | 5.6                 | 12.0      |
| 150432f            | 11.0                       | 9.6                         | 10.7             | 8.6            | 10.5                | 14.9      |
| 150432g            | 13.2                       | 8.0                         | 9.3              | 7.8            | 8.4                 | 12.9      |
| 150432h            | 12.3                       | 8.9                         | 8.0              | 5.8            | 7.3                 | 10.0      |
| 150432i            | 8.5                        | 7.3                         | 8.0              | 6.7            | 5.0                 | 7.8       |
| 150432j            | 7.8                        | 6.5                         | 6.8              | 5.7            | 3.0                 | 4.6       |
| 150432k            | 6.3                        | 4.5                         | 5.0              | 3.4            | 2.2                 | 3.5       |
| 150432-l           | 5.0                        | 4.0                         | 4.3              | 3.8            | 1.9                 | 3.2       |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2-14 of King), Cibolo Formation.

LOCALITIES.—Neal Ranch: USNM 701, 701a, 701a<sup>3</sup>, 701c, 701d, 701h, 701k, 701-l, 706x, 708y, 721g, 727d, 727e; Cibolo: 728-l.

DIAGNOSIS.—Large *Diplanus* with flattened umbonal region and moderately strong costellae.

TYPES.—Holotype: USNM 150432a; figured paratypes: 150431a, 150432e, g, h, i, k, 150433a-c, 150434a-c, 153496a-u, 153500; measured paratypes: 150432 b-l.

COMPARISON.—*Diplanus catatonus* most nearly resembles *D. lamellatus* (R. E. King). It differs primarily in its relatively narrower pseudodeltidium that occupies only about one-third of the total hinge width. Other differences are less distinct: the ornamentation of *D. catatonus* is normally a little stronger than that of *D. lamellatus*, and the hinge is wider. The outline of the brachial valve is more transverse in typical *D. catatonus* and more elongate in *D. lamellatus*, although there are many specimens that cannot be distinguished by this feature alone. The average size of *D. catatonus* is greater, and so is the maximum size.

Strong costation and flattened umbonal region

distinguish *D. catatonus* from *D. apochordus*; strong costation and strong lamellation distinguish it from the Sicilian species *D. sinuatus* (Merla). *Diplanus catatonus* normally is larger than *D. redactus*, new species, and has a wider hinge relative to total width of shell, but also a wider pseudodeltidium, relative to total width of hinge. The pedicle interarea of typical *D. catatonus* is much higher and its apical angle smaller than in *D. redactus*, although some specimens do resemble *D. redactus* in this feature, inasmuch as it partly depends on the shape of the object to which the shell is attached, and, therefore, it is a highly variable feature.

DISCUSSION.—*Diplanus catatonus* lived attached to some solid object, and its shape was influenced by the shape of this object. Since the shell normally was attached by a large part of the pedicle valve, the shape and ornamentation of the valve are highly variable and not reliable in distinguishing species.

*Diplanus lamellatus* (R. E. King)

PLATE 47: FIGURES 1-42; PLATE 48: FIGURES 1-39; PLATE 49: FIGURES 1-5; PLATE 49: FIGURES 6-12; PLATE 50: FIGURES 15-20



*Streptorhynchus lamellatum* R. E. King, 1931:49, pl. 4; fig. 1 [not figs. 2, 3].

*Diplanus lamellatus* (R. E. King) Stehli, 1954:300, pl. 17: figs. 27-29.

Shell distorted cone; pedicle valve irregularly conical, brachial valve lidlike, moderately convex; outline transversely subelliptical to longitudinally subquadrangular or trapezoidal, widest anterior to midline of brachial valve. Hinge narrow, straight; pedicle interarea long, narrow, convex, or twisted, bisected by relatively wide pseudodeltidium occupying well over one-third of total hinge width and normally wider than either lateral part of interarea. Brachial valve interarea low, divided by wide convex chilidium that nearly obscures flat parts of interarea. Brachial valve umbo posteriorly blunt, with 2 dimples, 1 on each side of axis; brachial valve ornamented by strong radial costae, only slightly interrupted by somewhat weaker circum-

umbonal lamellae. Ornamentation of pedicle valve similar, but normally weaker and more variable due to attachment of that valve to foreign objects.

Pedicle valve interior devoid of plates or septa, hinge teeth projecting from beneath palintrope, extending as converging ridges along sides of pseudodeltidial cavity toward apex of valve. Muscle area slightly depressed in some individuals, normally indistinct, asymmetrical.

Brachial valve interior shallow, concave, with strong, long bilobed cardinal process, each lobe of which may be slightly bifid at end; line of division between 2 halves of process produces a groove along its posterior length. Dentifer strongly flexed and fused to anterior side of cardinal process; hinge sockets deep, formed by sides of cardinal process and fused brachiophores. Muscle area indistinct, slightly depressed, subdivided by low median ridge.

MEASUREMENTS (in mm).—

|                      | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|----------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 703bs           |                            |                             |                  |                |                     |           |
| YPM 11399 (holotype) | 11.8?                      | 9.7                         | 12.5             | 9.7            | 6.0                 | 9.2?      |
| USNM 150450a         | 15.6                       | 9.7                         | 14.0             | 9.0            | 7.0                 | 14.8      |
| 150450b              | 12.8                       | 9.6                         | 10.3             | 6.8            | 5.0                 | 9.9       |
| 150450c              | 12.5                       | 9.6                         | 10.0             | 6.7            | 5.0                 | 8.3       |
| 150450d              | 10.7                       | 6.2                         | 8.0              | 5.3            | 6.0                 | 9.4       |
| 150450e              | 7.9                        | 7.5                         | 8.3              | 5.2            | 4.5                 | 8.0       |
| 150450f              | 7.4                        | 6.0                         | 6.1              | 4.4            | 4.3                 | 6.9       |
| 150450g              | 6.9                        | 6.7                         | 6.0              | 4.3            | 3.7                 | 6.3       |
| 150450h              | 5.2                        | 4.2                         | 5.0              | 3.6            | 2.8                 | 2.9       |
| 150450i              | 4.3                        | 3.8                         | 4.8              | 4.0            | 2.0                 | 2.8       |
| USNM 702d            |                            |                             |                  |                |                     |           |
| 150446a              | 11.4                       | 10.0                        | 11.0             | 8.6            | 5.8                 | 11.8      |
| 150446b              | 13.9                       | 10.2                        | 12.5             | 8.9            | 8.5                 | 13.7      |
| 150462a              | 10.7                       | 9.8                         | 9.7              | 7.3            | 7.2                 | 14.8      |
| USNM 707a            |                            |                             |                  |                |                     |           |
| 150455a              | 10.4                       | 10.4                        | 12.3             | 8.7            | 5.3                 | 9.6       |
| 150455b              | 11.9                       | 10.5                        | 13.1             | 9.0            | 7.0                 | 13.7      |
| 150454a              | 13.9                       | 10.7                        | 11.5             | 8.4            | 12.3                | 19.0      |
| AMNH 631             |                            |                             |                  |                |                     |           |
| 152588a              | 17.1                       | ?                           | 13.1             | 8.7            | 8.3                 | ?         |
| 152588b              | ?                          | 10.5                        | 12.8             | 10.6           | ?                   | ?         |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Hess Formation (Taylor Ranch Member), Cathedral Mountain Formation and Cathedral Mountain (Wedin Member), Cibolo Formation.

LOCALITIES.—Bone Spring: AMNH 492, 625, 628, 631, 658, 660, USNM 725c, 728e, 728f, 728h; Decie Ranch: USNM 707a; Poplar Tank: USNM 707h, 707ha, 718v, 718z; Sullivan Peak: USNM 707d, 707g, 707-1, 713c, 714y, 722h, 722-1, 727a; Skinner Ranch (low): USNM 705a, 715v; Skinner Ranch

(high): USNM 705r, 714y; Taylor Ranch: USNM 702d, 702e; Cathedral Mountain: AMNH 500, 500K, USNM 700x, 702, 702a, 702 (low), 702un, 703bs, 708, 712o, 721u, 723u; Wedin: USNM 700-1, 700x, 714w, 717e, 723v, 727p; Cibolo Formation: USNM 725v, 738r, 738s.

DIAGNOSIS.—Small *Diplanus* usually with strongly and narrowly umbonate brachial valve and strong costellae anteriorly.

TYPES.—Holotype: YPM 11399; figured paratypes: YPM 11398a, b; figured hypotypes: USNM 150444a, 150446a, b, c, d, 150454a, 150541a, 150459a, 150462a, b, 150470a, 153498a-c, f, 153499a, 153501, 153502a, b, 153503a, b, 153504, 153505, 153506, 153507; measured hypotypes: 150450a-i, 150446a, b, 150454a, 150455a, b, 150462a, 152588a, b.

COMPARISON.—*Diplanus lamellatus* is characterized primarily by its relatively wide pseudodeltidium and subquadrate to trapezoidal outline with widest part anterior to the midline. The hinge commonly appears to be narrower than in *D. catatonus* and in *D. redactus*, new species. It is further distinguished from the latter species by its normally more deeply conical pedicle valve with higher and more narrow interarea. Wolfcampian and Leonardian species are distinguished by the short brachial valve interarea, the lack of well-defined lamellae, and the nonflaring nature of the costellae at the anterior. On the inside, the thickness and narrowness of the cardinalia are distinctive.

*Diplanus rarus*, new species

PLATE 30: FIGURES 11-12; PLATE 50: FIGURES 1-14, 21-31;  
PLATE 93: FIGURES 20-29

Fairly large for genus, longer than wide, sides broadly rounded but anterior somewhat narrowly rounded; pedicle valve conical, moderately elongated; hinge narrower than midwidth and with small auriculations. Attachment surface occupying at least half of ventral surface. Costellae fairly even in size, about 6 in 5 mm at front of large specimen.

Pedicle valve moderately deep and moderately convex; interarea forming broad triangle, pseudodeltidium occupying about one-fourth the width; pseudodeltidium moderately convex. Ridge margining interarea sides grooved on anterior side. Anterior moderately curved in dorsad direction where free from attachment.

Brachial valve with umbonal region narrowly swollen, moderately steep umbonal slopes leading to the ears. Median region strongly swollen; anterior forming steep slope; lateral slopes steep. Interarea short, lying at slight angle to pedicle valve interarea and not overhanging opposite interarea.

Pedicle valve interior with thick, closely spaced teeth. Brachial valve interior with moderately long cardinal process and thick socket plates.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 714p          |                            |                             |                  |                |                     |           |
| 150472a (holotype) | 18.5                       | 13.5                        | 15.6             | 11.4           | 5.4                 | 12.4      |
| 150472b            | 14.0                       | 14.0                        | 18.8             | 15.4           | 11.5                | 20.5      |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Sullivan Peak Member); Cibolo Formation (Breccia Zone of Udden).

LOCALITIES.—Skinner Ranch: USNM 714p; Decie Ranch: USNM 707a; Sullivan Peak: USNM 733j; Cibolo: USNM 728-1.

DIAGNOSIS.—Fairly large *Diplanus* with median swollen brachial valve and fairly even ornament.

TYPE.—Holotype. USNM 150472a; figured and measured paratype: 150472b; figured paratypes:

153497a, b; unfigured paratypes: 150472c-e; figured specimens: 153049a, b, 153512a-c.

COMPARISON.—In size this species approaches *D. apochordus*, but the pedicle valve is not so elongated, the umbo of the brachial valve is not arched, and the costellae are fairly even in size. It approaches *D. catatonus* in size, but it has a stronger brachial valve and somewhat narrower pseudodeltidium.

DISCUSSION.—This species comes from the Decie

Ranch Formation as does *D. apochordus*, but the two have completely dissimilar appearance. They both occur in bioherms with *Scacchinella* and *Eolyttonia*, suggesting a tendency toward diverse speciation in different bioherms.

***Diplanus redactus*, new species**

PLATE 50: FIGURES 32-45

Low, shallow, irregular cone; brachial valve gently convex, pedicle valve low conical. Outline nearly circular, truncated by relatively narrow, straight hinge line. Pedicle interarea short for genus, a broad-based triangle bisected by very narrow pseudodeltidium occupying one-fifth to one-fourth of hinge width. Brachial valve interarea

short, continuing plane of pedicle interarea, or slightly concave, bisected by chilidium of low relief. Shell thick, constructed of circum-umbonal laminae, wide spaced for genus; costae quite regular, with 1 weak costa inserted by intercalation between stronger costae that originated farther back on umbo; costae only slightly interrupted by laminae.

Pedicle valve interior unknown, presumed to be devoid of plates and similar to that of other species of *Diplanus*.

Brachial valve interior shallow, concave, with short, stout, bifid cardinal process fused with dentifers that diverge widely below process. Muscle area well defined, slightly raised, bisected by very low, rounded median ridge. Sockets shallow.

MEASUREMENTS (in mm).—

|           | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-----------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701e |                            |                             |                  |                |                     |           |
| 150475a   | 19.4                       | 16.6                        | 21.7             | 15.0           | 7.0                 | 12.0      |
| USNM 700a |                            |                             |                  |                |                     |           |
| 150474a   | 10.6                       | 9.4                         | 10.9             | 6.3            | 3.0                 | 4.7       |
| 150474b   | 13.2                       | 10.8                        | 10.5             | 7.3            | 5.0                 | 4.0?      |

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (middle and upper bed 10 of P. B. King, *Uddenites*-bearing Shale Member).

LOCALITIES.—Bed 10: USNM 700, 700a; *Uddenites*: USNM 701, 701e, 701-1, 701v.

DIAGNOSIS.—Generally depressed and rounded *Diplanus* with fairly regular ornament and moderately prolonged interarea on the pedicle valve.

TYPES.—Holotype: USNM 150475a; figured paratype: 150474a, 150475b; measured paratypes: 150474a, b; unfigured paratype: 150474b.

COMPARISON.—*Diplanus redactus* is characterized by its low, broad interarea with relatively narrow pseudodeltidium and by its unusually regular ornamentation. The low interarea and regular ornamentation are the most obvious differences from *D. catatonus*. Its narrower pseudodeltidium differentiates it from similarly shaped specimens of *D. lamellatus*. The brachial valve interior seems to have more widely divergent dentifers than in typical specimens of other species of *Diplanus*, but the description of this interior is based on a single specimen, so the range of variability is not known.

DISCUSSION.—Our collection of *D. redactus* is

small, only nine specimens; however, these maintain their characteristic features through considerable range in size, and we believe that they represent a valid species.

**Subfamily DERBYOIDINAE Thomas, 1958**

Orthotetidae, usually of large size, having cup-like sockets but with the secondary median septum of the pedicle valve incipient to well formed.

*Derbyoides* was separated by Dunbar and Condra (1932) from *Derbyia* because of difference in the cardinalia. Actually, a difference also exists in the ventral septa of the two genera, that of *Derbyia* being strong, crested, and united with the pseudodeltidium, whereas that of *Derbyoides* is secondary and usually in an incipient state of development. The other members of this subfamily represent other extremes. *Tapajotia* is almost identical to *Derbyoides*, but it has a somewhat lesser development of the ventral median elevation, which is an incipient ridge. *Permorthotetes* is distinguished by a strongly developed median septum that forms a small apical chamber with false dental plates of small size.

### Genus *Derbyoides* Dunbar and Condra, 1932

PLATE 26: FIGURES 1-4; PLATE 34: FIGURES 1-8; PLATE 35: FIGURE 18; PLATE 43: FIGURE 2; PLATE 126: FIGURES 48, 49

*Derbyoides* Dunbar and Condra, 1932:114.—Mendes, 1956:18.—Campbell, 1957:21.

*Tapajotia* Dresser, 1954:33.—Mendes, 1956:149.

Convexiconcave, flatly biconvex, planoconvex to shallow conical; outline transversely subovate to quadrate; hinge narrower than midwidth, occasionally slightly auriculate. Costellae moderately strong, rounded to sharp, added anteriorly by insertion, weakly crenulate; growth interruptions of lamellae moderately strong, more frequent near margins. Pedicle valve nearly flat to moderately conical; anterior profile normally concave; interarea wide, short to moderately long, slightly convex or concave, rarely flat; perideltidial area plainly marked; pseudodeltidium widely expanding, completely arched, deeply notched for chilidium, normally with shallow median groove or median flattening. Brachial valve nearly flat to moderately convex; interarea present but short; chilidium strong, strap-like, fitting into arcuate notch of pseudodeltidial arch.

Pedicle valve interior with strong hinge teeth projecting forward at edges of pseudodeltidium, extending apically as convergent dental ridges, meeting at apex of valve; median septum low, thickened along free edge, bisecting muscle area, apical end independent of dental ridges, or braced to them by shell thickening or small secondary plates of adventitious callus. Muscle area flabellate, excavated or raised, occupying one-third to two-thirds of valve length, the proportion greater in deeper valves; adductor scars elongate, on each side of low septum or myophragm; diductor scars broadly flabellate, lateral to and surrounding adductors. Floor of valve striate, striae stronger near margins.

Brachial valve interior with short, thick, bilobed cardinal process, each lobe longitudinally grooved and the proximal end partially covered by chilidium; dentifers thick, divergent, forming shallow cuplike sockets, joining beneath digits of cardinal process, often with median septum or carina between myophores, which is extended ventrally as a thick point; erisma absent, muscle area bilobate, normally bisected by low myophragm. Valve floor pustulose and striate, striae stronger near margin.

TYPE-SPECIES.—*Derbyoides nebrascensis* Dunbar

and Condra (1932:115, pl. 9: fig. 3, pl. 14: figs. 1-4 [fig. 1: lectotype herein designated]).

TYPES.—Figured hypotypes: USNM 150427a-h.

COMPARISON.—*Derbyoides* is characterized by its concave or nearly flat to moderately conical pedicle valve, wide, normally short interarea, widely expanding and completely arched pseudodeltidium. Another distinguishing feature is the low and weak median ridge that normally is somewhat thickened along its crest, is cemented at its apical end by callus, and does not have pseudodental plates to produce a small chamber or camera. Features of the brachial valve that distinguish the genus are the short but thick cardinal process that fits into the notch of the pseudodeltidium, rather than extending under it and straddling the median septum of the pedicle valve; the large brachiophore plates that recurve toward the hinge to form cup-like sockets and lack of supporting plates.

*Derbyoides* is easily distinguished from *Derbyia* Waagen (emended, Girty, 1908) by its low pedicle median ridge, widely expanding and completely arched pseudodeltidium, short cardinal process, recurved brachiophore plates, and lack of supporting plates. Presence of a median septum in the pedicle valve distinguishes *Derbyoides* from *Schuchertella* Girty, *Schellwienella* Thomas, and *Pulsia* Ivanov, which are the three genera like it externally. Presence of a camera or chamber at the juncture of the median septum with the dental ridges has not been observed in *Derbyoides*. This is the chief distinction between it and *Orthotetes*, which commonly has a small primary chamber in the apical part of the pedicle valve. The chamber is often filled by callus, which makes differentiation of the two difficult.

The cuplike sockets and the internal details of *Goniarina* suggest *Derbyoides*, but the known species of that genus are generally small, conical forms that do not have a strong myophragm or median ridge in the pedicle valve and in which the brachial valve is provided with a club-shaped ridge anterior to the adductor field. The type-species of *Derbyoides* has a low myophragm in the adductor field that extends anterior to the anterior margin of the field, but it seems not to develop the club shape and anteriorly confined position of the ridge in *Goniarina*, nor does it have the long dentifers of

*Goniarina*. The two genera appear sufficiently close to be placed in the same family.

DISCUSSION.—We are using genus *Derbyoides* for species having cuplike sockets in the brachial valve that are formed by the welding of the dentifer to the cardinal process and to the side of the valve. These species also have a median ridge or myophragm, often reaching the proportions of a septum in the pedicle valve. This, however, is not fused to the dental ridges to form a small chamber, as in *Orthotetes*.

*Derbyoides* is rare in the Glass Mountains and comes from the Gaptank Formation, the *Uddenites*-bearing Shale Member of the Gaptank Formation, and the upper 15 feet of the Gray Limestone of P. B. King. The specimens are poorly silicified, fragmentary, or not silicified.

*Derbyoides dunbari*, new species

PLATE 35: FIGURES 27–30

Average size for genus, flatly biconvex, often slightly distorted and asymmetrical outline transversely subovate to nearly semicircular; hinge slightly narrower than midwidth, normally not auriculate; commissure rectimarginate or slightly wavy. Costellae strong, rounded or sharp, added anteriorly by insertion, numbering about 20 in 5 mm; intertroughs shallow rounded, weakly transversely filate; growth interruptions moderately strong, widely spaced, closer near margins.

Pedicle valve flatly convex to shallowly conical at apex; anterior profile convex, concave or flatly sigmoidal; no attachment scars visible. Interarea wide, long, nearly flat to slightly convex, meeting plane of commissure at small to moderately large obtuse angle, commonly asymmetrical; perideltidial area well marked, about half width of interarea; pseudodeltidium widely expanding, broadly and completely arched with median flattening as shallow groove, deeply notched at anterior for reception of dorsal chilidium and cardinal process.

Brachial valve moderately convex; chilidium strong, arcuate; interarea very short or absent.

Pedicle valve interior with strong, widely divergent hinge teeth, extending apically as strongly convergent, low, rounded dental ridges, meeting at apex, where they are often buried in callus; median septum low, upper edge rounded, thickened, bisecting muscle area, apical end buried in callus. Muscle area bilobate, slightly elevated or depressed, adductor scars along median septum, diductor scars wide, lateral and anterior to adductors. Valve floor weakly striate, more strongly so near margins.

Brachial valve interior with short, wide, strong bifid cardinal process having underside with median ridge, attached end partly covered by chilidium, dentifers fused to sides of process, mostly buried by callus. Muscle area broad, bilobed, slightly excavated or raised, bisected by low myophragm. Floor of valve weakly striate, stronger near margins.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701           |                            |                             |                  |                |                     |           |
| 150424a (holotype) | 42.5                       | ?                           | 51.2             | 44.6           | 13.4                | ?         |
| 150424b            | ?                          | 27.3                        | 35.3             | 30.0           | ?                   | 6.3       |
| 150424c            | 41.5                       | ?                           | 55.0*            | 38.8?          | 7.8                 | ?         |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of bed 2, bed 4, both of P. B. King).

LOCALITIES.—USNM 701, 701–1.  
DIAGNOSIS.—Irregularly distorted *Derbyoides* with strongly apsacline to procline interarea.

TYPES.—Holotype: USNM 150424a; figured paratype: 15042b; unfigured paratypes: 150424c–f; measured paratypes: 150424c.

COMPARISON.—*Derbyoides dunbari* is character-

ized by its somewhat distorted, flatly concave pedicle valve with wide, short interarea that meets the plane of commissure at a small obtuse angle, and its strong, normally rounded costellae. It is much flatter and larger than *D. marathonensis*, new species, with which it occurs at USNM 701, and its pseudodeltidium is wider, the median septum and hinge teeth stronger, and its cardinal process wider and more heavily built. This species resembles the type-species, *D. nebrascensis* Dunbar and Condra,



but it differs primarily in its less regular shape, more elongate outline, stronger costellae, interarea that meets the plane of commissure at a smaller angle, its brachial median ridge not terminating as a knob, and by the presence of low crural plates bordering the muscle area.

DISCUSSION.—This species is very rare. The specimens are not well silicified, especially in the region of the muscle scars, which were greatly thickened in life.

*Derbyoides marathonensis*, new species

PLATE 35: FIGURES 19–26

Small for genus, biconvex to nearly planoconvex, shallow to moderately deeply conical; outline transversely semioval to subquadrate; hinge slightly narrower to slightly wider than midwidth; occasionally weakly auriculate. Costellae moderately strong, rounded to sharp, weakly crenulated, added anteriorly by intercalation and numbering about 14 in 5 mm on both valves; intertroughs narrow to nearly as wide as costellae; growth lines widely spaced, moderately strong, more frequent near margins.

Pedicle valve with concave anterior profile; attachment scars obscure; interarea moderately long, wide, normally convex, rarely concave, occasionally asymmetrical, meeting plane of commissure at small

obtuse angle; perideltidial area less than half width of interarea; pseudodeltidium wide, completely arched, with median flattening or shallow groove, deeply notched for reception of chilidium.

Brachial valve nearly flat to gently convex; chilidium arcuate, projecting posteriorly; interarea absent. Sulcus irregularly developed.

Pedicle valve interior with hinge teeth projecting forward at edges of pseudodeltidium, extending apically as dental ridges, meeting at apex of valve; median septum low, upper edge thickened, apical and independent of dental ridges, or cemented to it by callus. Muscle area bilobate, bisected by median septum, raised or forming a shallow excavation, adductor scars wide, flabellate, located in delthyrial cavity, diductor scars wider, anterior to adductors. Valve floor striated, striations stronger near margins.

Brachial valve interior with short, bifid cardinal process, with attached side partly covered by chilidium, secondary shell or socket plates fused to sides and underside of process, forming large, shallow sockets; dentifers divergent, projecting bluntly into body chamber, ends recurved slightly toward hinge; muscle field nearly circular, bisected by low myophragm continuous to median notch of cardinal process. Floor of valve striated, with stronger striae near margins.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| 150425a (holotype) | 12.3                       | ?                           | 18.0?            | 18.0           | 5.4                 | 5.4       |
| 150425b            | 11.5                       | ?                           | 14.2?            | 12.9           | ?                   | 1.9       |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of bed 2 of P. B. King).

LOCALITY.—USNM 701.

DIAGNOSIS.—Small with subconical pedicle valve and fairly long median ridge in the pedicle valve.

TYPES.—Holotype: USNM 150425a; figured paratypes: 150425c–e; unfigured paratypes: 150425b, f–h; measured paratype: 150425b.

COMPARISON.—*Derbyoides marathonensis* is characterized by its small size, its conical pedicle valve with small, poorly developed median septum, relatively narrow pseudodeltidial arch, and short narrow cardinal process. These features distin-

guish it from *D. dunbari*, new species, with which it occurs at USNM 701, and from *D. nebrascensis*, the type-species.

*Derbyoides* species 1

PLATE 62: FIGURES 1, 2

An unsilicified specimen of medium size has the characteristics of *Derbyoides*. It is strophomenoid in form and profile, about 33 mm long and 53 mm wide, a compressed shell with a thickness of 6.5 mm. The surface is costellate, the costellae thin and distant, numbering 8 to 5 mm at the front margin.

The interarea is short, the brachial valve gently convex and the pedicle valve gently concave. The specimen comes from the Gaptank Formation at USNM 701y.

Types.—Figured specimen: USNM 153801.

### *Derbyoides* species 2

A pedicle and brachial valve of large size indicate another species of *Derbyoides*, but the specimens are too poor for naming or detailed description. The pedicle valve is 54 mm long by 76.5 mm wide. The brachial valve is 54 mm long by 73 mm wide and is strongly convex. The pedicle valve is fairly deeply concave. The costellae are distant and number 6 in 5 mm at the anterior margin of the pedicle valve. They come from the upper part of the *Uddenites*-bearing Shale Member at USNM 713g.

Types.—Described specimens: USNM 153480a, b.

### Superfamily DERBYIACEA Stehli, 1954

Costellate Strophomenida with erismata in the brachial valve.

The Derbyiacea appear first in the early Pennsylvanian and become abundant in the late Pennsylvanian. They reach their greatest development in numbers of species and genera in the Permian. They are especially abundant in the Wolfcamp, when they contributed conspicuously to bioherms in the Neal Ranch and Skinner Ranch formations.

### ORTHOTETELLIDAE, new family

Derbyiacea having a primitive type of cardinal process intermediate between that of the Derbyoidinae and Derbyiidae.

The character of the cardinal process is the basis for the family. The myophores are lobate like those of *Derbyoides*, and they are cleft medially like those of *Derbyia* but are bifurcated. *Orthotetella* is also like *Derbyia* in the presence of long flaring erismata.

### Genus *Orthotetella* R. E. King, 1931

*Orthotetella* R. E. King, 1931:51.—Stehli, 1954:302.

Large, thin shelled, biconvex to convex-concave,

hinge wide, often slightly auriculate; costellae low, sharp, added by insertion; intertroughs wide, flat, concentrically ornamented by transverse fila that have little effect on costellae; growth laminae prominent near margins, concentric wrinkling prominent. Pedicle valve normally flatly convex to concave or forming a shallow to deep cone; interarea laterally wide, short to moderately long; pseudodeltidium completely arched, dorsally expanding without monticulus or median depression. Brachial valve flatly and evenly convex, with costellae somewhat stronger and more closely spaced.

Pedicle valve interior with strong teeth projecting from underside of interarea, extending apically as dental ridges, converging at apex of valve; median septum short or absent, often buried by apical callus; dental plates converging to form Y-shaped spondylium near apex, but continuing dorsad beyond its attachment on valve floor, to produce a U-shaped spondylium fused to crests of dental ridges, whole structure forming, with pseudodeltidium, a conical tube. Muscle marks within spondylium.

Brachial valve interior with short, blunt, bilobed cardinal process, each lobe longitudinally slit and serrate, joining to produce median groove of process; dentifers fused to sides of process, forming laterally and dorsally open hinge sockets and projecting bluntly into body chamber; erismata continuous with dentifers diverging into umbonal cavity, outlining part of muscle area. Chilidium usually complete. Muscle area broad, bisected by low median ridge; muscle marks faint longitudinal striae.

TYPE-SPECIES.—*Orthotetella wolfcampensis* R. E. King (1931:51, pl. 9: figs. 27-28).

COMPARISON.—*Orthotetella* differs from *Derbyia* externally by its sharp, widely spaced costellae with transversely filose intertroughs, and its broadly arched nonsulcate pseudodeltidium. Internally the long, expanding conical spondylium distinguishes this genus from all its relatives in the Orthotetacea. *Orthotetella* resembles *Hypopsia* in ornament and profile, but generally it is larger. The spondylium of *Hypopsia* suggests that of *Orthotetella* in early stages, but it becomes sessile rather than tubular in adult specimens.

DISCUSSION.—King (1931:51) remarked the supposed absence of a median septum, and the ab-

sence of any median seam marking the juncture of the two spondylial plates. The absence of a seam is the result of the formation of the spondylium, not by the junction of two dental plates, as King supposed, but by splitting of the upper edge of a small median septum. The spondylium arises from the floor of the valve, and its sides fuse to the crests or sides of the dental ridges, but they are structurally independent of them. In some specimens, including the holotype (King, 1931, pl. 9: figs. 28a-c), the median septum is small or absent, or it may be buried in callus near the apex, but even in these the spondylium arises from the floor of the valve and is not formed by the joining of two dental plates. This structure is formed in a manner just the reverse of that in *Orthotetes* or *Ombonia*.

Muscle marks were not seen on the outside surface of the spondylium, as stated by King (1931: 51), but they appear as striae on its inner surface. In some specimens the outer surface of the spondylium is gently marked, but these marks are results of slightly irregular growth of the structure, or reflect the muscle marks on the inside.

In the juvenile pedicle valve the septum bearing the spondylium is slender and delicate, but, with increasing age, it is greatly thickened, although not much extended along the valve floor in an anterior direction. The thickening is considerable in some specimens, is irregular, and appears to have been laid down in successive layers. In specimens in which the juvenile was attached on a fairly broad surface the spondylium is completely sessile and the septum takes the form of a thick buttress under the spondylium, where it lifts away from the floor. In some specimens from the Glass Mountains, which have a long interarea and in which the pedicle valve is fairly deep, the spondylium is extremely long and the septum is likewise longer than usual.

The walls of the spondylium and the material enlarging the septum are clearly of secondary nature because they contain pseudopunctae; furthermore, some specimens show the walls of the spondylium attached outside the dental ridge, but, in others, it is exactly continuous with the anterior edge of the dental ridge. A specimen from USNM 701p shows this to perfection. The outer thick wall of the spondylium is of secondary pseudopunctate material of the fibrous layer, which is laid on the outside of a thin band of lamellar shell extending from

the tooth and lining the inside of the spondylium. This is probably the original wall of the spondylium. Inside this layer a lamellar inner layer lines the entire inner tubular cavity, the layers being continuous across the teeth and joining the spondylial wall with the pseudodeltidium.

The cardinalia of the brachial valve suggest *Derbyia* but have some important differences. The margin of the chilidium is entire and thus the pseudodeltidial edge is neither sulcate nor does it bear a raised ridge. In old shells the outer rim of the chilidium remains entire, but plates are extended forward over the myophore for some distance, which must be inserted under the edge of the pseudodeltidium. These plates are separated medially by a narrow gap, but they do not seem to affect the form of the pseudodeltidium.

The myophore is primitive, short, like that of *Derbyoides*, and the cleft between the lobes is shallow, not forked. Each lobe bears a wide slit, and the underside of the cardinal process medially bears a short ridge or longitudinal thickening. The dentifer is small and inconspicuous, but the erismata are broad and widely extended. The ensemble is like that of a compressed *Derbyia* cardinalia in which the various parts of the cardinal process were unable to develop ventrad toward the valve interior.

### *Orthotetella wolfcampensis* R. E. King

PLATE 93: FIGURES 4-19; PLATES 94: FIGURES 1-18;  
PLATE 95: FIGURES 23-27

*Orthotetella wolfcampensis* R. E. King, 1931: 51, pl. 9: figs. 27-28.—Stehli, 1954:303, pl. 17: figs. 24-26, pl. 18: figs. 1-2.

Large, biconvex to rarely convexi-concave, shallow to deeply conical, relatively symmetrical to strongly distorted, with irregular concentric undulations and bumps; outline transverse, semioval to nearly semicircular; hinge slightly narrower to slightly wider than midwidth, slightly auriculate in some specimens; commissure irregular but without consistent folding. Costellae low, sharp, added by insertion, often slightly crenulate when well preserved, numbering about 10 in 5 mm on each valve, slightly stronger on brachial valve; intertroughs broad, flat, transversely filose; growth lines unevenly spaced, becoming stronger and more frequent near margins.

Pedicle valve flatly to deeply conical, rarely con-

cave; interarea short to moderately long, wide, fairly symmetrical to slightly twisted, normally flat, rarely slightly concave or convex, meeting plane of commissure near right angle, normally apsacline to procline; perideltidium occupying less than half width of interarea; pseudodeltidium broadly arched, dorsally expanding.

Brachial valve flatly to moderately and evenly convex.

Pedicle valve interior with strong teeth projecting from underside of interarea, forming strong dental ridges meeting at apex; median septum short or absent, often buried in callus at apex, bifurcating near apex to form Y-shaped spondylial plates that fuse to crests or sides of dental ridges, continuing dorsally beyond its junction with the valve floor, to produce a U-shaped spondylium with plates continuously fused to dental ridges, thus forming an elongate dorsally expanding cone with the broad

arch of the pseudodeltidium. Muscle marks faint to deeply impressed longitudinal striae on floor and sides of spondylium. Valve floor faintly costellate anteriorly, costellae stronger near margins.

Brachial valve interior with short, blunt, straight, bilobed cardinal process; each lobe longitudinally slit for full length, insides of slits finely serrate, lobes joining to produce median groove of process, a continuation of notch at free ends; dentifer fused to sides of process, forming groovelike, laterally open hinge sockets and projecting bluntly and slightly into body chamber; erismata continuous with dentifers, widely diverging into umbonal arch, defining posterolateral boundaries of muscle area. Chilidium small, entire. Muscle area, broadly bilobate, bisected by low myophragm; muscle marks faint longitudinal striae. Valve floor faintly costellate, costellae stronger near margins.

#### MEASUREMENTS (in mm).—

|           | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|-----------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 701k |                                     |                                      |                          |                        |                             |                  |
| 151218    | 5.0                                 | ?                                    | 7.1                      | 6.7                    | 5.7                         | ?                |
| USNM 701p |                                     |                                      |                          |                        |                             |                  |
| 151219    | 13.0                                | ?                                    | 24.0?                    | 19.0?                  | 7.0?                        | ?                |
| USNM 701h |                                     |                                      |                          |                        |                             |                  |
| 151217a   | 49.9                                | ?                                    | 64.0?                    | 62.0?                  | 20.0                        | ?                |
| 151217b   | 47.6                                | 47.6                                 | 56.7                     | 55.2                   | 28.3                        | 44.5             |
| 151217c   | 53.0?                               | ?                                    | 70.0?                    | 64.0?                  | ?                           | ?                |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 2, 12–14 of P. B. King).

LOCALITIES.—Bone Spring: AMNH 628, USNM 728e, 728f; *Uddenites*: USNM 701p, 701x, 703p; Neal Ranch (bed 2): USNM 701; (beds 12–14): USNM 701a, 701c, 701h, 701j, 701k, 727d, 727e.

DIAGNOSIS.—Large costellate, subconical shells with long tubular spondylium in the pedicle valve.

TYPES.—Holotype: YPM 11366; figured hypotypes: USNM 151040a, b, 151214a, d, e, 151217, 151218a, b, d, 151223d, n, 153479; unfigured hypotypes: USNM 151214b, c, 151218c, 151223a–m.

COMPARISON.—More than one species may be present in the specimens studied, but the number of individuals is too few to be sure. No other species of the genus is now known.

*Orthotetella wolfcampensis* is characterized by its shallow to moderately deeply conical valve with interarea that meets the plane of commissure near a right angle, its broadly arched pseudodeltidium, sharp costellae, and broad, transversely filose intertroughs. Internally the species is distinguishable by its long conical spondylium, which extends the entire length of the underside of the interarea and is free of the floor except near the apex. The peculiar spondylium, however, is a generic character, and, until other species of *Orthotetella* are known, it is impossible to determine what features of the spondylium may be of specific value.

Externally *O. wolfcampensis* resembles the larger and deeper species *Derbyia profunda*, new species, and *D. nasuta* Girty. Its characteristic costellation and especially broadly arched pseudodeltidium distinguish it from these species. It resembles

superficially some individuals of *Nothopindax egregius*, new species, but it can be distinguished by its costellation and broad pseudodeltidial arch as well as by its characteristic internal features.

DISCUSSION.—Several excellent specimens in the USNM collection show that the spondylium of *Orthotetella wolfcampensis* is not constructed like that of most other genera. The spondylium in species of *Geyerella*, for instance, is formed by two dental plates that join above the floor of the valve and thus form a spondylium and median septum. In *O. wolfcampensis* the spondylium is produced by splitting of the upper edge of a small median septum that arises from the floor of the valve. The two branches meet and fuse with the dental ridges, simulating dental plates and forming the conical tubular spondylium.

Variation in *O. wolfcampensis* involves the spacing of the costellae, the angle of projection and relative width of the interarea, the convexity of both valves, and the fortuitous irregularities in the shell walls. In addition, the median septum that gives rise to the spondylium varies in height and length: in some specimens, including the holotype (King, 1931, pl. 9: fig 28c.), the septum is so short and stubby as not to have the appearance of a septum. Other specimens show the manner of construction of the septum and spondylium. Re-examination of those with short septa shows the apical narrowing of the base of the spondylium that indicates its origin from a rudimentary septum.

Unsilicified shells of this species show strong pseudopunctuation in the intertroughs between costellae and also in the septum and walls of the spondylium. Pseudopunctae are not visible on silicified shells.

This genus is very rare wherever it occurs. In the Glass Mountains it occurs from the *Uddenites*-bearing Shale Member into the upper part of the Neal Ranch Formation. It is no more diagnostic of the Permian than of the Pennsylvanian, but it tends to bear out the contention that the Wolfcamp fauna had its beginnings prior to the Gaptank. The species is also rare in the Bone Spring Formation, where it occurs in the basal part. Here, it occurs in a fauna somewhat younger than the Neal Ranch but, nevertheless, very closely related to it. King (1931:52) reports it from the Gym Formation (=Hueco) from the Hueco Mountains.

The present collection is too small to distinguish species of such variable form in the relatively long stratigraphic range exhibited by the known material. Only one complete specimen occurs in the collection, and this one had to be filled with plaster to hold it together. The specimens from the *Uddenites*-bearing Shale Member are not silicified, but the one brachial valve is large, measuring 50 by 60 mm. Specimens from the Gray Limestone or bed 2 of P. B. King are extremely delicate and very variable. These have a spondylium longer and more delicate than those from the Sierra Diablo. The septum is also longer and narrower, but this may be as much due to the size as to difference in kind.

Specimens from the beds 9–12 of Cooper (=beds 12–14 of P. B. King) must have reached enormous size. A specimen, only pieces of which now remain, appeared on the bottom of a block, was badly crushed and could not be held together. This measured about 100 mm long by about 150 mm wide before it collapsed. The shells of all the Glass Mountains specimens are extremely delicate and are preserved only with great difficulty.

#### Family DERBYIIDAE Stehli, 1954

Varied and progressive Derbyiaceae having wide and long supports (erismata) to the cardinal process and pedicle valve with septa or elaborate development of septa, plates, or spondylium.

The character binding the members of this family together is the elaborate development of the cardinal process with its widely divergent lateral supports. These are striking when compared to the cuplike socket region of the *Orthotetacea*. Subfamily characters appear in the nature of the pedicle valve whether dental plates meet or whether a median septum is present without dental plates.

#### Subfamily DERBYIINAE Stehli, 1954

Usually large Derbyiidae, pedicle valve with median septum and elaboration of the septum and dental plates.

This subfamily is based upon *Derbyia*, which appears first in the early Pennsylvanian and extends to the end of the Permian. The internal cone of *Orthotetella* could have been derived from a modification of *Derbyia*. Oddly, *Nothopindax* and *Or-*



*thotetella* appear at about the same time, but *Derbyia* outlived them to a significant degree.

Genera in the Permian of West Texas: *Derbyia* and *Nothopindax*.

Several genera based on minor aberrations of *Derbyia* are herein synonymized. *Plicatoderbyia* is submerged because the plications on which it is based are developed individually in several stocks of *Derbyia* (see below). *Derbyaeconcha* Licharew and *Grabauellina* Licharew are poorly defined shape variants of a normally extremely variable genus.

### Genus *Derbyia* Waagen, 1884

*Derbyia* Waagen, 1884:576, 591.—Hall and Clarke, 1892:261.—

Schellwien, 1900:10.—Girty, 1909:181.—Dunbar and Condra, 1932:75.—Sokolskaya, 1960:219.

*Derbyina* Grabau, 1931a:259, 262 [= *Grabauellina* Licharew, 1934].

*Plicatoderbyia* H. D. Thomas, 1937:13–18.

*Derbyaeconcha* Licharew, 1934a:507.

*Grabauellina* Licharew, 1934a:507.

Shell planoconvex, convexi-concave or bioconvex, nearly flat to deeply conical, commonly irregular and distorted, normally unplicated, but usually ornamented by weak or strong costellae and growth lines. Pedicle interior with forward projecting teeth, apically convergent dental ridges, and high median septum normally joined to inside of pseudodeltidium at apex and for variable distance anteriorly, less commonly septum cemented to outgrowths from dental ridges anterior to its attachment to pseudodeltidium, thus forming small shallow camera; muscle area wide and short to proportionately very long, excavated to elevated, commonly with elevated margins, bisected by medium septum. Brachial valve interior with long or short cardinal process, bifid at free end, supported by erismata that diverge anteriorly into umbonal cavity, outlining posterior edges of muscle area, dentifer a ridge on erismata. Chilidium small or absent, muscle area wide, short to long, slightly excavated.

TYPE-SPECIES.—*Derbyia regularis* Waagen (1884: 594, pl. 53: figs. 1–2, 4). Genolectotype by Hall and Clark (1892).

COMPARISON.—*Derbyia* is distinguished from other genera of the Derbyiinae by its prominent single median septum that normally joins directly to the inside of the arch of the pseudodeltidium

near the apex, without dental plates and without spondylium. In several species the septum may be joined to the dental ridges by outgrowths from one or both dental ridges, sometimes producing a shallow secondary spondylium.

DISCUSSION.—Features of *Derbyia* deserving special mention and description appear in both valves. The occasional development of a spondylium-like chamber in the pedicle valve needs explanation because of its confusion with the small apical chamber that is an important character of *Orthotetes*.

The palintrope of *Derbyia* usually has a broad and flat interarea, and, in some species, it is conspicuously developed. It is variable, as in other attached forms, and is often twisted, concave, or convex, depending on the surface of attachment. The pseudodeltidium is usually conspicuous. In some species and many young it is fairly strongly swollen and is strutted against the dental ridges. It is flattened in some large individuals, like that of *Meekella* or *Tropidelasma*, and, in those specimens, a well-developed monticulus is present. A well-marked groove appears in many specimens along the center of the pseudodeltidium that corresponds to a gap in the chilidium. Specimens having a fairly broad monticulus also have the median groove well developed. Pennsylvanian and lower Permian derbyias normally have the pseudodeltidium fairly swollen and occupying the entire delthyrium. The larger Permian species and later ones have the young stages with swollen pseudodeltidium, but the adult stages have the monticulus well developed and sides of the pseudodeltidium flat.

The relation of the median septum of the pedicle valve to the pseudodeltidium is of interest. The septum of young specimens is a thin blade that rises anteriorly to a sharp crest and usually has a steep anterior descent. The septum is anchored to the inner, apical part of the pseudodeltidium. In many specimens this attachment region is obscured by deposition of adventitious shell. The inner sides of the pseudodeltidium are margined by the dental ridges, which are the growth track of the teeth along the delthyrial edge. These do not unite with the median septum, but in many specimens shell substance is laid down from the proximal part of the dental ridge to the posterior of the septum to form a more or less complete chamber. This chamber is

present only in mature or old shells and has not been observed in young specimens. This chamber has been confused with that of *Orthotetes*, which is present only in young shells and may be completely covered or filled in adult stages. We see no confusion between *Orthotetes* and *Derbyia* when this is borne in mind. The camera of *Orthotetes* is primary, whereas that of *Derbyia* is a secondary character of adulthood or old age. The structure produced in *Permorthotetes* seems to be a secondary character.

The cardinal process of the brachial valve also is variable, changing with the depth of the pedicle valve. Usually the longer the beak of the pedicle valve, the longer the prongs of the cardinal process, with consequent changes in its other parts. The chilidium is developed best in the young and in the Pennsylvanian and Early Permian species. Later species and the gigantic forms have the chilidium aborted or absent. The chilidium in the young and smaller or early species consists of a short convex plate, usually divided by a deep median groove; essentially 2 convex plates located just ventrad of the posterior margin and on each side of the median line. They lie at the base of the dorsal surface of the shaft and taper laterally to disappearance. The chilidium affects the form of the pseudodeltidium. Specimens in which the median groove of the chilidium is deep and the sides well separated have the pseudodeltidium depressed to fit into the groove. This makes a low ridge on the under side of the pseudodeltidium and a longitudinal groove on the outside. This is the reason for the longitudinal groove seen on the pseudodeltidium of many species and specimens of *Derbyia*. In species of large size in which the chilidium persists it is usually flattened and worn, in some cases nearly smooth and almost to a point of disappearance. Some of the larger species such as *D. informis*, new species, and *D. magna* Branson lack the chilidium completely; consequently, the pseudodeltidium is flat and has a monticulus formed from an axial ridge developed on the cardinal process shaft.

As in other *Orthotetidina* the parts of the cardinal process of *Derbyia* are not easy to distinguish. The two divergent prongs of the cardinal process are joined by shell tissue, as in *Meekella*, into a more or less elongated shaft. The prongs vary in length and divergence, long in long-beaked shells

and short in others. The prongs usually are bisected by the high part of the median septum of the pedicle valve. The myophore is identified as a slit in each prong, open posteriorly and distally, where it usually is crenulated and is the former site of diductor attachment.

The shaft slopes laterally to form the erismata, and the dentifer is an oblique ridge on it. No fulcral plates were seen in any specimens of *Derbyia*, the teeth being inserted under the edge of the palintrope and on the dentifer. The dentifer is slightly elongated in some specimens to protrude beyond the supporting erismata. The latter are consistently widely flaring and may be very long.

Compared to *Meekella*, the general plan of *Derbyia* is similar, both having strong, flaring erismata and a myophore that is two-pronged. The cardinal process of *Meekella* normally is longer and somewhat compressed laterally; that of *Derbyia* is squatter and more spreading. *Derbyia* develops neither fulcral plates nor the promontorium that is so conspicuous in *Meekella*.

The companion genera *Orthotetes* and *Derbyia* have been subjects for controversy and confusion since they were established. The characteristics of *Orthotetes* were known poorly from the first, and, after *Derbyia* was established, it seemed to be a synonym of *Orthotetes* as then recognized. Girty (1909:181, 186) reviewed the problem and restricted the two names to separate groups of species, which he and Waagen both recognized as distinct from one another. Waagen (1884:592) established two "sections" of the genus *Derbyia*, calling those species with the median septum attached directly to the inside of the pseudodeltidium the "septati," and those with the septum attached to the dental ridges by short lateral plates (forming a little chamber) the "camerati." Girty (1909) noted that the holotype of Fischer's *Orthotetes radiatus*, the type-species, belongs to the "camerati," and that *Derbyia regularis* Waagen, which Hall and Clarke (1892) had designated as the type-species of *Derbyia*, belongs to the "septati"; therefore, Girty (1909:197) proposed to restrict the two available names to the two distinct "sections."

Specimens in the USNM collection present evidence that, in some species, the possession of a chamber, or of a septum that attaches directly to the center of the pseudodeltidium, may be a matter

of individual variation. On other grounds, Sokolskaya (1952:52; 1954:148) considered *Derbyia* to be synonymous with *Orthotetes*. She believes that the type-species, *Derbyia regularis* Waagen, actually belongs to the "camerati," and therefore is a species of *Orthotetes*. According to Thomas (1958:77), she did not base this contention on the holotype of *D. regularis* but drew her conclusions from specimens from the Moscow area that she had identified as the species. G. A. Thomas emphasized the necessity for re-examination of the holotype of *D. regularis* Waagen, not only to see if a camera is present, but also to determine whether the "socket plates" are recurved, as he thinks they are in *Orthotetes*, or extend into the umbonal arch, as in the many species that have been called *Derbyia*. This difference in the cardinalia of the two genera has been claimed by Campbell (1957:43) and Thomas (1958:77) to be a more reliable criterion for their distinction than the presence or absence of a camera or spondylium.

Grant had the opportunity to collect numerous specimens of *D. regularis*, both calcareous and silicified, from the type area in the Salt Range. All of those have the independent septum, and no primary camera, in contrast to specimens from the Lenox Hills Formation, where some ventral valves have one or two secondary plates connecting the socket ridges (dentifers) to the septum. *Derbyia* certainly is not near to *Orthotetes* morphologically.

Fischer's illustrations (1830, pl. 20: figs. 4a-b; 1837, pl. 20: figs. 4a-c; 1850, pl. 10) of the type-species, *Orthotetes radiatus*, have been reproduced by Girty (1908, pl. 4: figs. 1-2) and Sokolskaya (1954, text fig. 57). These show a pedicle valve that belongs to the section "camerati." Fischer did not illustrate the interior of a brachial valve. Sokolskaya has collected specimens from the Moscow Basin that she identified as *Orthotetes radiatus* Fisher (Sokolskaya, 1954: 145, pl. 14: figs. 3-5, pl. 16: fig 7). In addition she offers a schematic drawing (text fig. 55) of the interior of the brachial valve of an *Orthotetes*, showing the cardinal process and the dorsal plates. This illustration is reproduced by Thomas (1958, fig. 3B). If these drawings represent a typical brachial valve from the type area of the genus in the Moscow Basin, they support the contention of Campbell (1957) and Thomas (1958) that the cardinalia of *Orthotetes* are significantly

different from those of *Derbyia*. The plates of *Orthotetes* recurve and do not extend into the umbonal cavity.

Specimens of *Orthotetes radiatus* Fischer in the USNM collection have the characteristic primary spondylium in the pedicle valve and cardinalia as illustrated by Sokolskaya. The structures of these are exactly like those of specimens in the United States from Middle and Late Mississippian rocks. From these and the above data we conclude that *Orthotetes* is a recognizable Mississippian genus and that it does not occur in Permian rocks in its typical form. It is also clear that *Orthotetes* and *Ombonia* are not synonyms as hinted by Williams (pers. comm. in Thomas, 1958:13). Inspection of our plates illustrating the latter genus and the text describing it make it clear that neither the spondylium nor the cardinalia are anything like those of *Orthotetes*.

The *Treatise* (Williams, et al., 1965) now recognizes *Ombonia* as a valid genus, but it gives no credence to the Omboniinae of Sokolskaya, which is justified because of the peculiar spondylium and cardinalia.

The name *Plicatoderbyia* was introduced by H. D. Thomas (1937:13-18) for a subgenus of *Derbyia*. He based the difference from *Derbyia* (*Derbyia*) on the presence of low plications of the shells of specimens from the Permian Phosphoria Formation of Wyoming (type-species: *Derbyia* (*Plicatoderbyia*) *magna* (Branson)). Specimens in our collections from the Glass Mountains, however, show that such plication appears sporadically in individuals of many species, *D. cincinnata*, *D. pannucia*, and *D. texta*, for example. In some specimens plication is radial, but in others it is oblique or irregular. None of the Glass Mountains species is free of plicated individuals, and in *D. pannucia* plicated specimens are nearly as common as non-plicated ones. This feature alone in *Derbyia* is not a reliable specific distinction and therefore certainly is not a valid feature upon which to base a subgenus. Furthermore, no stratigraphic significance can be attached to the secondary plication in Permian species because it appears early in the Wolfcamp and extends into the late Guadalupe.

Within the Glass Mountains species of *Derbyia* there are two groups. One group includes *D. crenulata* Girty, *D. laqueata*, and *D. filosa*, new species.

These are characterized by a relatively small average size and strong costellae that may be strongly or weakly crenulated. They are suggestive of *Derbyaeconcha* Licharew. Apparently crenulation of the costellae decreases in strength upward in the stratigraphic section.

The other group is characterized by a relatively large average size, a deep subconical pedicle valve with high interarea, and weak, fine costellae that may or may not be closely crowded and are not strongly crenulated, although individuals may be weakly crenulate.

With respect to the "camera" or false camera that is produced in some species by cementation of the median septum to the dental ridges by callus material that mimics dental plates, there seems to be no natural or consistent grouping of the species. Within the more strongly costellate group, however, the presence or absence of the camera is more consistent in the stratigraphically higher and lower species than in the intermediate ones; that is, most individuals of *D. crenulata* (Wolfcampian) and *D. filosa* (Guadalupian) have strong tendencies for development of the callus that produces the camera: it is entirely absent in only a few. In *D. laqueata* (Leonardian) most specimens do not have pseudodental plates or a camera, but some do. In *D. texta* (Leonardian) most specimens have no camera, but a few do.

In the deeply conical group there is no such biostratigraphic trend with respect to this feature.

### *Derbyia bella*, new species

PLATE 64: FIGURES 1-45; PLATE 65:  
FIGURES 16-34

Small to medium size for genus, outline rectangular, hinge wide terminating in small ears; maximum width variable, ranging from hinge to short distance anterior to midvalve; sides moderately rounded in anterior half, concave to oblique in posterior half; anterior margin usually broadly

rounded. Anterior commissure normally rectimarginate, usually with an eccentric dorsad wave on one side, in some specimens leading to unequal bilobation. Surface costellate, costellae narrowly rounded, closely crowded, with narrower interspaces, numbering 8 to 10 in 5 mm at 10 mm anterior to the beak, and 6 or 7 in 5 mm at front margin of adult 30 mm long. Costellae crenulated, about 4 crenulations per millimeter at margin of average specimen. Costellae of pedicle valve less crowded, with wider interspaces than brachial valve.

Pedicle valve normally deeper than brachial valve, concave in lateral profile but varying to flat or slightly convex; interarea moderately long, usually apsacline. Pseudodeltidium convex and medially grooved. Umbonal slopes steep; median region usually gently convex but forming central convex region that descends to flanks.

Brachial valve ranging from flat (in young) to unevenly but moderately convex in lateral profile; anterior profile broadly convex with long sloping sides. Interarea vestigial; chilidium reduced; umbonal region flat; region just anterior to umbo swollen and rounded forming poorly defined mound; anterior half medially flattened or gently sulcate and tending to bilobation. Lateral slopes of cardinal extremities gentle.

Pedicle valve interior with small elongated teeth; median septum (uniseptum) reaching to about midvalve, elevated and thin and attached to the posterior half of the pseudodeltidium. Muscle scars not impressed.

Brachial valve interior with short, forked myophore, small dentifer, and broad shallow sockets.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2 and 4 of P. B. King).

LOCALITIES.—Bed 2: USNM 701; bed 4: 701-1, 727e.

DIAGNOSIS.—Small to medium size, strongly costellate and crenulate, usually with a wide hinge.

## MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 701-1         |                                     |                                      |                          |                        |                             |                  |
| 151025a            | 28.9                                | 28.7                                 | 37.6*                    | 32.7                   | 13.2                        | 20.8             |
| 151025b            | 26.0                                | 25.0                                 | 31.4                     | 30.3                   | 9.2                         | 18.7             |
| 151025c (holotype) | 22.7                                | 19.0                                 | 26.8                     | 25.5                   | 7.4                         | 15.2             |
| 151025d            | 19.6                                | 17.9                                 | 25.1                     | 22.4                   | 10.0                        | 15.2             |
| 151025e            | 20.8                                | 18.7                                 | 24.0                     | 21.7                   | 6.3                         | 12.6             |
| 151025f            | 17.2                                | 17.0                                 | 23.3                     | 24.0                   | 7.7                         | 13.2             |
| 151025g            | 18.4                                | 14.6                                 | 19.0                     | 18.0                   | 6.4                         | 11.8             |
| 151025h            | 13.3                                | 12.1                                 | 14.7                     | 15.1                   | 6.9                         | 8.5              |
| 151025i            | 9.6                                 | 8.1                                  | 10.8                     | 8.7                    | 3.9                         | 5.7              |
| 151025j            | 8.2                                 | 6.5                                  | 8.3                      | 7.4                    | 3.5                         | 5.2              |

**TYPES.**—Holotype: USNM 151025c; figured paratypes: 151025b, c, e, h, 153189a–f, 153279a–d, 153280a–e, 153285a, b; unfigured and measured paratypes: 151025a, a, d, f, g, i, j; unfigured paratypes: 153279a.

**COMPARISON.**—This species attains approximately the same size as *D. carteri*, new species, but it is somewhat more square and the young are definitely less transverse than the young of *D. carteri*. Costellae are stronger and are more strongly crenulated than those of *D. carteri*.

*Derbyia bella* has about the same strength of costellae and crenulations as *D. crenulata* Girty, but it does not attain the large size of that species, it is not so strongly transverse, and it usually has a longer interarea than the Sierra Diablo species. *Derbyia crenulata* often is thickened at the anterior by growth at right angles to the shell margin. *Derbyia bella* also has this feature, but the anterior margin is not so ragged as that of *D. crenulata*, a feature well marked in the holotype of *D. crenulata*.

**DISCUSSION.**—*Derbyia bella*, like *D. carteri*, forms clusters of shells and many of the specimens etched from the rock are attached to their brothers and to any other handy species.

*Derbyia carteri*, new species

PLATE 30: FIGURES 2–6; PLATE 65: FIGURES 1–15;

PLATE 66: FIGURES 1–47

*Derbyia buchi* R. E. King (not D'Orbigny), 1931:59, pl. 8: figs. 4–6.

Medium to large for genus, wider than long and transversely rectangular in outline; hinge wide, equal to, or slightly exceeding, width anterior to hinge; cardinal extremities variable, usually near right angle but occasionally auriculate. Sides slightly oblique to gently rounded. Anterior commissure usually deformed, variable often with reversed wave in the form of broad S. Surface multicostellate, costellae increasing by intercalation in at least 3 generations, 12–14 costellae in 5 mm at 10 mm anterior to beak and about 8 in 5 mm at anterior margin of large adults. Surface often concentrically wrinkled and with strong growth lamellae.

Pedicle valve gently convex to nearly flat and often anteriorly geniculated in lateral profile; anterior profile broadly and moderately convex; interarea short; pseudodeltidium broad, strongly convex but median groove not prominent. Median region somewhat swollen longitudinally, with flanks sloping gently to the margins.

Brachial valve fairly evenly and moderately convex in lateral profile; broadly domed, with flattened top and short steep sides in anterior view. Interarea and chilidium vestigial; umbonal region flattened; median region with poorly defined sulcus extending from the swollen anteroumbonal region to margin.

Pedicle valve interior with uniseptum not usually reaching mid-valve; septum thin and delicate even in thick-shelled specimens; septal crest variable, usually near the middle, septum and dental ridges



forming small chamber in some specimens. Muscle area moderate in size, rim thickened and completely bisected by uniseptum.

Brachial valve interior with modified bilobed

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701k          |                            |                             |                  |                |                     |           |
| 151020a (holotype) | 35.0                       | 33.6                        | 49.0             | 48.5           | 7.8                 | 25.8      |
| 151020b            | 36.9                       | 31.8                        | 46.6             | 48.2           | 10.8                | 20.5      |
| 151020c            | 27.8                       | 27.8                        | 38.9             | 42.6           | 10.4                | 22.3      |
| 151020d            | 37.8                       | 29.8                        | 43.5             | 44.0           | 11.7                | 19.7      |
| 151020e            | 27.5                       | 26.0                        | 33.8             | 33.9           | 7.7                 | 19.5      |
| 151020f            | 28.5                       | 25.1                        | 33.0             | 31.6           | 7.1                 | 14.6      |
| 151020g            | 25.0                       | 23.7                        | 32.8             | 30.6           | 8.6                 | 13.4      |
| 151020h            | 24.7                       | 20.4                        | 28.4             | 29.6           | 7.0                 | 11.6      |
| 151020i            | 21.2                       | 18.8                        | 27.8             | 24.0           | 9.0                 | 15.2      |
| 151020j            | 17.0                       | 16.2                        | 22.4             | 21.7           | 5.6                 | 8.5       |
| 151020k            | 12.2                       | 12.0                        | 18.0             | 15.6           | 2.9                 | 5.8       |
| 151020-l           | 7.7                        | 6.8                         | 10.2             | 10.0           | 3.0                 | 4.6       |

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 2–12 of P. B. King).

LOCALITIES.—*Uddenites*: USNM 701f, 701q; Neal Ranch (bed 2): 701; (bed 4): 701d, 721g, 727e; (bed 12): 701a, 701a<sup>1</sup>, 701c, 701h, 701k, 742c.

DIAGNOSIS.—Large crenulate *Derbyia* with fairly strong costellae, wide hinge, and fairly short interarea.

TYPES.—Holotype: USNM 151020a; figured paratypes: 151020b, c, f, j, 153281a–g, 152282a–c, 153283; unfigured measured paratypes: 151020b, d, e, g–i.

COMPARISON.—This species is best compared with *D. crenulata* Girty, which is often wide hinged and auriculate, but *D. carteri* is more finely and more evenly costellate than the Sierra Diablo species and also is usually not ragged along the anterior margin. *Derbyia carteri* does not attain the large size reached in some specimens of *D. crenulata*.

*Derbyia bella*, new species, is not to be confused with *D. carteri* because the latter usually is larger, with finer and more even costellae. The young of *D. bella* are more nearly square than those of *D. carteri*, which generally are more transverse in the adult form as well.

DISCUSSION.—The apex of the pedicle valve of *D. carteri* is the site of deposition of considerable callus. This usually obscures the place of contact

chilidium, and moderately long, narrowly forked myophore, dentifers short and blunt; supporting plates elongated and wrapping around the outside of muscle field.

of the median septum with the pseudodeltidium. If the deposition is not complete, a small gap may be left between the septum and the roof of the pseudodeltidium, which will simulate the chamber characteristic of *Orthotetes*.

This species forms large clusters and predominates in the bioherms in which it occurs. Many specimens are cemented into clusters and many are surrounded by possible algal material to make patch reef assemblages. Occurring with them and cemented on them are individuals and clusters of *Teguliferina*. *Derbyia carteri* is abundant in its particular bioherm, but it is not widely distributed.

The species is named for John L. Carter, Carnegie Museum, Pittsburgh, who helped us collect in 1963.

### *Derbyia cincinnata*, new species

PLATE 79: FIGURES 1–21; PLATE 80: FIGURES 1–17

Small to large, flatly convex, thin walled, normally symmetrical; outline transversely subelliptical to semicircular; hinge slightly narrower than widest part of shell, auriculate in some specimens; commissure wavy but without consistent folds; both valves discontinuously plicate, with plications undulating in their courses, producing alternately bumps and hollows in braided pattern. Costellae moderately strong, somewhat alternating in

strength, weakly crenulate, relatively little displaced by irregularities in shell; number on either valve near 17 in 5 mm; growth lines weak, irregularly spaced over surface of valve, not necessarily more frequent near margins.

Pedicle valve nearly flat, anterior profile flat to slightly concave or convex; interarea low, flat, or nearly so, meeting plane of commissure at right or small obtuse angle; arch of pseudodeltidium wide, with shallow median groove; perideltidium reaching beyond half distance from midline to edge of interarea at hinge.

Brachial valve flatly convex, more convex than pedicle valve, braided irregularity of shell in more distinctly radial pattern, approaching genuine radial plication.

Pedicle valve interior with long hinge teeth; extending posteriorly as dental ridges along edges of pseudodeltidium, converging at apex of valve; median septum low because valve is flat, upper edge forming large obtuse angle, apical and buried in callus that also buries junction of dental ridges.

Muscle area as long as median septum, normally rather long because valve is flat, occupying more than half length of valve, weakly impressed, with faint muscle marks consisting of longitudinal striae. Valve floor bumpy, faintly costellate, costellae becoming strong near margins.

Brachial valve interior with short, weak, curved cardinal process, shallowly bifid at free end, each prong longitudinally slit, with serrations in the slits; dentifer fused to sides of process, forming very shallow, open hinge sockets; projecting slightly into body chamber; erismata continuous with dentifers, diverging widely and deeply into umbonal arch, defining posterolateral boundaries of muscle area. Chilidium present, well developed, bisected by continuation of median groove of cardinal process. Muscle area anteriorly expanding, faintly impressed, bisected by low median ridge, muscle marks consisting of faint longitudinal striae occupying about one-third length of valve. Floor of valve bumpy and plicate, faintly costellate, costellae strong near margins.

#### MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 702c          |                                     |                                      |                          |                        |                             |                  |
| 151136a            | 5.3                                 | 5.6                                  | 7.7                      | 6.8                    | 1.9                         | 3.2              |
| 151136b            | 16.9                                | 17.8                                 | 22.4                     | 12.0?                  | 11.0?                       | 16.0?            |
| 151136c            | 19.5                                | 20.3                                 | 25.8                     | 19.0                   | 7.8                         | 17.6             |
| 151136d            | 26.8                                | 27.2                                 | 31.2                     | 22.0                   | 6.2                         | 17.2             |
| 151136e (holotype) | 32.6                                | 35.0                                 | 39.9                     | 33.4                   | 12.0                        | c.25             |
| 151136f            | 38.6                                | ?                                    | 54.0                     | 33.6                   | 11.0                        | ?                |
| 151136g            | 29.0                                | 28.0                                 | 33.9                     | 27.0?                  | 14.5                        | 24.2             |
| USNM 703d          |                                     |                                      |                          |                        |                             |                  |
| 151135a            | 41.7                                | ?                                    | 56.5                     | 40.0?                  | c.14                        | ?                |
| 151135b            | 53.0                                | ?                                    | 75.8                     | 62.8                   | 7.5                         | ?                |
| USNM 710u          |                                     |                                      |                          |                        |                             |                  |
| 151139a            | 42.6                                | 38.4                                 | 52.3                     | 45.2                   | 16.9                        | 28.8             |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 702, 721u, 726o, 726u, 726x, 735g; Road Canyon: AMNH 503, USNM 702c, 703, 703c, 703d, 707e, 709c, 710u, 716xa, 719x, 720d, 721j, 721o, 721s, 721t, 721y, 721z, 722e, 722g, 724a, 724b, 724c, 724d, 726d, 726e, 726f, 726z, 726za, 732j, 736x.

DIAGNOSIS.—*Derbyia* of moderate size with strongly "braided," bumpy ornament.

TYPES.—Holotype: USNM 151136e; figured para-

types: 151131a, 151134a, 151135a, 151136c, 151137a, 151139a, 151141a, 151143a, b, 151150a, b, 153284; unfigured paratypes: 151131b, 151134b, 151135b, 151136a, b, d, f, g, 151137b, 151141, 15150b; measured paratypes: 151135a, b, 151136a-d.

COMPARISON.—*Derbyia cincinnata* is characterized by strong bumpy ornamentation that gives the surface of the shell a braided appearance, by a low and wide interarea, low convexity of both valves, wide pseudodeltidial arch, relatively well-developed chilidium, strong but rather crowded costellae, me-

dian septum and dental ridges that are buried in callus despite the near right angle at which the interarea meets the plane of commissure, and short and weak, but nevertheless curved, cardinal process. Most of these features distinguish it from the species that it most resembles: *D. pannucia*, new species. The latter may have irregularities of the shell that approach the pattern on *D. cincinnata*, but a narrow pseudodeltidial arch (and consequently no chilidium), a thicker shell wall, finer and more closely spaced costellae, normally deeper pedicle valve, and much stronger cardinal process.

In its plication and costellation *D. cincinnata* is similar to *Orthotetes magnus* Branson (1930:26), which H. G. Thomas (1937:14) designated as the type-species of his subgenus *Derbyia* (*Plicatoderbyia*). *Derbyia cincinnata* differs in its transverse rather than elongate outline, smaller average and maximum size (Branson's smallest specimen is 7 mm longer than the largest specimen from the Glass Mountains, and his largest specimen is more than twice as long), stronger plication that is less continuous and more bumpy, its flatter pedicle valve with lower and wider interarea and wider pseudodeltidial arch. Internally *D. cincinnata* differs in its weaker and shorter cardinal process.

DISCUSSION.—Despite its other distinctive characteristics, *Derbyia cincinnata* is based primarily on its peculiar plication. At first we thought that these wrinkled shells were aberrant individuals of several other species, but it was impossible to determine to which species the specimens might belong.

The species varies primarily in its auriculation, in its convexity, and in the pattern of the wrinkling of the shells. The extremes range from relatively random scattered nodes to nearly straight plications. The more regular and continuous plications occur on brachial valves, whereas the typical pedicle valve best exhibits the braided or discontinuously plicate pattern. Smaller shells are more convex, larger shells flatter. Convexity is greater in the brachial valve.

The collection of this species is too small to give a significant distribution pattern in a count of the density of costellation.

### *Derbyia complicata*, new species

PLATE 81: FIGURES 4–38; PLATE 88: FIGURES 1–6

Small, narrow hinged, subquadrate in outline and with the length and width variable; hinge commonly auriculate; maximum width usually anterior to midvalve, but variable. Anterior commissure variable, with wave toward either valve. Sides usually oblique to concave posteriorly but rounded anteriorly; anterior margin broadly rounded to slightly emarginate. Surface unequally costellate, costellae strongly crenulated, size varying, stronger ones setting off bundles of smaller. Costellae averaging about 13 at 10 mm anterior to beak, 10 mm at anterior margin of brachial valve; costellae on pedicle valve averaging about 11 at 10 mm anterior to beak, 10 at anterior margin.

Pedicle valve usually gently concave in anterior profile, but broadly and gently convex in anterior profile; interarea varying from nearly procline to apsacline, usually the latter; interarea variable but usually moderately long; pseudodeltidium usually prominently arched but with median depression varying from barely visible to absent. Perideltidial area not clearly visible. Umbonal region moderately swollen; umbonal slopes moderately concave to notched anterior to auricles.

Brachial valve unevenly convex, umbonal and anterior region moderately curved, but median region flattened to swollen in lateral profile; anterior profile gently to moderately domed. Umbonal slopes steep, lateral, and anterolateral slopes gentle to moderately steep.

Pedicle valve interior with strong, long teeth, not strongly thickened dental ridges uniting at apex; median septum delicate, short, forming obtuse angle in lateral view and with steep anterior slope; muscle region not strongly impressed, marginally thickened and reaching from one-third length to about midvalve.

Brachial valve interior with prominent bilobed chilidium; cardinal process short, not deeply bifurcated, lobes slightly divergent, but each lobe marked by deep serrated slit; dentifers not strongly developed; erismata widely divergent but short.

## MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 714w          |                                     |                                      |                          |                        |                             |                  |
| 151198a            | 23.2                                | 18.5                                 | 27.9                     | 17.3                   | 7.0                         | 15.5             |
| 151198b            | 22.4                                | 20.1                                 | 24.9                     | 16.4                   | 6.0                         | 15.9             |
| 151198c            | 17.5                                | 14.7                                 | 16.4                     | 11.5                   | 6.9                         | 13.3             |
| 151198d            | 18.0                                | 15.3                                 | 18.3                     | 12.3                   | 4.9                         | 10.4             |
| 151198e            | 13.1                                | 12.5                                 | 15.4                     | 10.2                   | 4.1                         | 10.0             |
| 151198f            | 13.4                                | 11.7                                 | 14.7                     | 10.2                   | 4.6?                        | 7.9              |
| 151198g            | 9.3                                 | 7.5                                  | 9.7                      | 7.7                    | 3.7                         | 4.9              |
| 151198h (holotype) | 21.0                                | 18.7                                 | 24.4                     | 18.0                   | 6.9                         | 16.0?            |
| 151198i            | 17.1                                | 17.1                                 | 22.4                     | 19.1                   | 6.7                         | 13.5?            |
| 151198j            | 14.2                                | 13.1                                 | 16.1                     | 13.2                   | 6.4                         | 10.0             |
| 151198k            | 11.8                                | 9.3                                  | 11.4                     | 10.6                   | 5.0                         | 8.1              |
| 151198-l           | 16.2                                | 16.2                                 | 21.7                     | 18.3                   | 6.0                         | 11.9             |
| USNM 702           |                                     |                                      |                          |                        |                             |                  |
| 151192             | 23.7                                | 18.9                                 | 23.7                     | 17.6                   | 4.0                         | 11.4             |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (*Institella* beds) and Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500H, 500N, USNM 700-1, 700x, 702, 702 (low), 702un, 703b, 708, 714w, 714wa, 717e, 721u, 723u, 723v, 726o, 726u, 727p; Road Canyon: USNM 703, 703a, 703c, 703d, 707e, 716x, 719x, 721y, 724a, 726d, 732j, 736x.

DIAGNOSIS.—Small, auriculate *Derbyia* with strong and unequal crenulate costellae and radial plications.

TYPES.—Holotype: USNM 151198h; figured paratypes: 151198d, i, j, m-q, 151190a, 151192, 153450a-c; measured paratypes: 151198a-g, i-l, 151192; unfigured paratypes: 151198a-c, e-h, k, l.

COMPARISON.—This may be compared with *Derbyia texta*, new species, more than with any other species. It differs from the Word form in having more diversified ornament, auriculate hinge, and the stronger development of radial plications. The brachial valve of *D. texta* appears to be less convex than that of *D. complicata* and the pseudodeltidium of the opposite valve is more distinctly grooved medially than that of the Cathedral Mountain species.

DISCUSSION.—Although plication of the shell in *Derbyia* is known in many species, it usually takes the form rather of oblique wrinkling than of uniform radial folding. Some specimens of *D. complicata* are so strongly and regularly folded as to be confused with *Meekella* or *Kiangsiella*. Such

folding would be regarded as generic in character if it were persistent and permanent. Some specimens of *D. complicata*, however, have the plication scarcely developed or only incipient. These specimens are difficult to separate from *D. texta*, but usually the ornament is sufficiently different to make separation possible. The plicated forms make an interesting study in a homeomorphic development because they so closely parallel *Kiangsiella* and *Meekella*.

*Derbyia crenulata* Girty

PLATE 75: FIGURES 10-28

*Derbyia? crenulata* Girty, 1909:183, pl. 26: figs. 5-5d.

*Derbyia crenulata* Girty.—Stehli, 1954:301.

Not *Derbyia? crenulata* R. E. King (not Girty), 1931:58.

Moderately large to large, thick walled, biconvex, comparatively flat to slightly conical, shape modified by attachment, but not normally greatly distorted; outline transversely subelliptical to subquadrate; hinge slightly narrower to slightly wider than midwidth, normally somewhat auriculate; commissure usually with a tendency to sulcation, rarely with slight irregular plication. Costellae strong, high, weakly to strongly crenulate, increasing by insertion, with earliest costellae near beaks commonly remaining strongest, giving ribbed appearance; costellae on pedicle valve normally somewhat weaker, sharper, more widely spaced, fewer in number, 6 to 7 in space of 5 mm; costellae on

brachial valve stronger, more rounded, often with concave sides, closely crowded, more strongly crenulate, 6 in space of 5 mm, all costellae remaining strong to shell margins and often protruding to make a rough edge, especially in the young. Growth laminae normally strong only near margins.

Pedicle valve forming shallow, irregular profile moderately concave to nearly flat, less commonly convex; interarea short and wide, flat, slightly concave or convex, rarely attenuate; strongly apsacline; pseudodeltidium broadly arched, anterior expanding, bisected by shallow groove; perideltidium slightly raised above lateral edges of interarea, extending less than half way from midline to hinge end on each side, border of perideltidium usually not parallel to lateral border of interarea.

Brachial valve flatly and uniformly convex, slightly greater convexity of any region dependent upon distortion of shell; median region anteriorly sulcate, sulcus irregular, ranging from perceptible to deep.

Pedicle valve interior with large, stout teeth, converging posteriorly as dental ridges along underside of pseudodeltidium, meeting at apex of valve, or slightly anterior to apex; median septum bladeliike, height directly dependent upon convexity of valve, upper edge with definite change in slope, angle depending upon height of septum, posterior of septum joining underside of pseudodeltidial arch between dental ridges near apex of valve, normally cemented to dental ridges by shell material arising from wall of valve independently of

ridges or septum, confluence of ridges, septum, and shell-wall material forming shallow chamber for reception of cardinal process in some specimens, and normally obscuring direct attachment of septum to underside of pseudodeltidial arch. Muscle area as long as median septum, occupying about  $\frac{1}{3}$  the total valve length, excavated or raised, with obscure borders or high bordering rim, more than one kind may occur in one valve, on either side of septum. Floor of valve with obscure costellae becoming stronger near edges.

Brachial valve interior with short to moderately long, slightly curved cardinal process, shortly bifid at free end, retaining groove between prongs right to hinge edge, thus bisecting chilidium, each prong longitudinally slit along most of length of posterior edge, slits finely serrate for reception of muscle attachments; dentifers firmly cemented to sides of process, projecting anteroventrally beneath process forming open hinge sockets, projecting bluntly into living chamber; erismata diverging into umbonal arch, bounding posterior margins of muscle area. Chilidium small but distinct, bisected by groove in cardinal process, appearing as 2 small pads on each side of process and just beneath hinge of pedicle valve. Hinge straight, with very short palintrope or bearing edge near center, tapering to knife edge laterally. Muscle area large, lobate, not strongly impressed, normally occupying about  $\frac{1}{3}$  length of valve, longitudinally striate. Floor of valve radially costellate, with costellae becoming stronger near edges.

#### MEASUREMENTS (in mm).—

|                   | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|-------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USGS 3764         |                                     |                                      |                          |                        |                             |                  |
| 118499 (holotype) | 19.7                                | 19.4                                 | 26.4                     | 28.2                   | 5.0                         | 11.0             |
| AMNH 625          |                                     |                                      |                          |                        |                             |                  |
| 151048            | 47.4                                | ?                                    | 66.7?                    | 54.6                   | 16.4                        | 15.0?            |
| USNM 705a         |                                     |                                      |                          |                        |                             |                  |
| 151045a           | 30.6                                | 26.7                                 | 31.2                     | 26.5                   | 9.4                         | 22.3?            |
| 151045b           | 28.5                                | ?                                    | 40.5                     | 33.5                   | 8.3                         | 9.6?             |

STRATIGRAPHIC OCCURRENCE.—Basal Bone Spring Formation, Skinner Ranch Formation (base, top, Decie Ranch, Poplar Tank, Sullivan Peak members), Hess Formation (Taylor Ranch Member), Cibolo Formation.

LOCALITIES.—Bone Spring: AMNH 625, 628, 631,

696, 699, USGS 3764 (green), USNM 728e, 728f, 728h; Skinner Ranch (base): USNM 705a, 707w, 711p, 715v, 720e, 720f, 728g; Decie Ranch: USNM 720g; 707g; Skinner Ranch (top): AMNH 520, USNM 705r, 727a; Poplar Tank: USNM 707ha; Sullivan Peak: USNM 707d, 710d, 722h,



722-1, 727a; Taylor Ranch: USNM 702d, 702e; Cibolo: USNM 728-1.

DIAGNOSIS.—Small *Derbyia* with fairly even, crenulated costellae.

TYPES.—Holotype: USNM 118499; figured hypotypes: 151045c, d, 151047a, b, 151048, 153287; unfigured hypotypes: 151045a, b.

COMPARISON.—*Derbyia crenulata* is characterized by short interarea with normally auriculate hinge ends, thick strong costellae that are crowded together but relatively few in 5 mm and are normally strongly crenulated. Internally it is characterized by the cementation of the posterior end of the median septum to the dental ridges anterior to the apex of the valve and by the relatively well-developed chilidium on the brachial valve.

This species most closely resembles *Derbyia texta*, new species, and *D. laqueata*, new species. It differs from the former in its usually unplicated brachial valve, wider hinge, shorter interarea, lower convexity, and its strongly crenulate costellae. Internally, the median septum of *D. crenulata* normally is braced to the dental ridges of pseudo-dental plates or amorphous callus, whereas the septum of *D. texta* normally remains independent of the ridges. *Derbyia crenulata* differs from *D. laqueata* in its normally less convex and thinner shell, wider hinge, and shorter interarea, weaker and less frequent growth lines, stronger costellae that are fewer per unit distance, and in its pseudo-dental plates.

Another coarsely costellate species is *D. filosa*, new species, which occurs high above *D. crenulata*, in the Word Formation. It differs from *D. crenulata* in its stronger, less densely spaced and more coarsely crenulate costellae, smaller maximum size, lower interarea, and shorter cardinal process.

*Derbyia profunda*, new species, is very different in appearance, and the two are unlikely to be confused. *Derbyia profunda* is normally larger, much deeper, nonauriculate, weakly costellate, weakly crenulate, and its median septum is attached for a long distance anteriorly to the inside of the pseudodeltidial arch of one or both dental ridges. *Derbyia nasuta* Girty occurs with *D. crenulata*. It is deeply conical like *D. profunda* and differs from *D. crenulata* in many of the same features. In addition, the average number of costellae per 5 mm is much

greater in *D. nasuta* than in either *D. crenulata* or *D. profunda*.

Other species of *Derbyia* from the Glass Mountains are readily distinguishable from *D. crenulata*. They have more and weaker costellae per unit distance, none are as strongly crenulate, and all are more deeply conical or thicker. *Derbyia texta*, new species, normally is smaller, somewhat plicate, and has the median septum completely free of the dental ridges to the apex of the pedicle valve. *Derbyia profunda*, new species, is much larger, deeper, and has weaker noncrenulate costellae. *Derbyia pannucia*, new species, also much larger, is very irregular, bumpy, and distorted, has the dental ridges separate from the median septum, and lacks a chilidium. *Derbyia cincinnata*, new species, is very flat, irregularly wrinkled, and plicated, and has low, rounded costellae that may not be crenulate.

A species similar to *D. crenulata* is *D. arellanoi* Cooper (1953) from the Permian of Sonora, Mexico. Its costellae are high and blunt, but they are not crenulate, and apparently are just as strong and as dense on the pedicle valve as on the brachial; the brachial valve is more strongly convex and has maximum convexity at the umbo; the perideltidium extends on each side more than half the distance from the median groove of the pseudodeltidium to the hinge ends; the shell shows no tendency to be auriculate or sulcate. *Derbyia arizonensis* McKee (1941:226, under the name *D. regularis*) is similar, but it differs from *D. crenulata* in having weaker, less strongly crenulate costellae that are much more widely separated, numbering only 6-7 in the space of 5 mm.

Among other American Permian species, *D. crenulata* differs from *D. multistriata* (Meek and Hadyen), as illustrated by Dunbar and Condra, (1932:101, pl. 10: figs 1-5), by its characteristic ornamentation and especially by its flatter brachial valve and less concave valve. *Derbyia cymbula* Hall and Clarke (1892:348; also Dunbar and Condra, 1932:97) has a strongly concave pedicle profile, finer ornamentation, and proportionately narrower hinge than *D. crenulata*. *Derbyia hooserensis* Dunbar and Condra (1932:92) has weakly crenulate costellae, and its size and shape are similar to *D. crenulata*. It differs primarily in its lower and weaker costellae.

The Pennsylvanian species *D. bennetti* Hall and Clarke (see Dunbar and Condra, 1932) and *D. deercreekensis* Dunbar and Condra (1932:90) resemble *D. crenulata* in their coarse costellae, which may be crenulate. Both of these species are more convex than *D. crenulata*, especially in the brachial valve, and *D. bennetti* has a higher interarea, proportionately narrower hinge, and stronger laminae of growth. *Derbyia crassa* (Meek and Hayden) also is similar to *D. crenulata*, differing primarily in its noncrenulate to weakly crenulate costellae that number only 5–10 in 5 mm and in its proportionately narrower, nonauriculate hinge. *Derbyia crassa* var. *texana* Dunbar and Condra is even more similar to *D. crenulata*, differing only in the above-mentioned features of ornamentation and in the slightly less developed tendency for auriculation.

No foreign species of *Derbyia* bears close resemblance to *D. crenulata*. Those described from the Salt Range of Pakistan by Waagen (1884) and Reed (1944) have weaker costellae that are not crenulate. The same is true of those described by Grabau (1931) from Mongolia and by Licharew (1932) from the Caucasus.

### *Derbyia elevata* R. E. King

*Derbyia elevata* R. E. King, 1931:59, pl. 8: fig. 7.

This species at present is completely unintelligible because the holotype is so poorly preserved and the specimen so incomplete that its real characters cannot be determined. It is preserved in solid chert and most of the anterior has been lost and the beak region and most of the pedicle valve have been destroyed. Furthermore, the brachial valve is revealed only partially, and a fraction only of the interarea of the pedicle valve is preserved.

That the species is a *Derbyia* cannot be questioned because of the large median septum in the pedicle valve, the remnants of forked cardinal process on each side of it, and the fine radial costellae on the only exterior surface preserved. The species was unusual in having a flattened brachial valve with a flattened umbonal region. The specimen is much flatter than the view given in R. E. King (1931, pl. 8: fig. 7a), which has been trimmed inaccurately.

This remnant of a specimen does not conform to any we found in the Glass Mountains. Its identity

with Girty's *Derbyia* species is very doubtful. Not only is there a size difference, but also the shape is entirely unlike the Capitan species, being strongly depressed in the direction of valve length. At present we are unable to identify any specimens as *D. elevata* and are unable to make a sensible reality out of the species.

STRATIGRAPHIC OCCURRENCE.—Identified by King as "Word Formation" but from float "lying on the surface of the upper Vidrio."

LOCALITY.—R. E. King 265.

TYPE.—Holotype: YPM 11417.

DISCUSSION.—In view of the poor quality of the specimen and the uncertainty of its stratigraphic position, the species can be given no significance in this work.

### *Derbyia filosa*, new species

PLATE 82: FIGURES 1, 2, 11–36

Small to moderately large, biconvex, relatively thin walled, shallowly conical, some shells moderately distorted; outline transversely subelliptical; hinge from half as wide to slightly wider than mid-width, normally slightly auriculate; commissure distorted with shell, most shells broadly rugose concentrically, slight tendency for sulcation of brachial valve, with some brachial valves gently plicate. Costellae strong, moderately high, some weakly crenulate, primary costellae stronger; number in 5 mm on pedicle valve between 10 and 16, growth lines conspicuous only near margins, where they form laminae. Obscure radial costae on some specimens.

Pedicle valve nearly flat to moderately convex, anterior profile gently convex or nearly flat, rarely concave; interarea low to moderately high, slightly concave or flat, rarely convex, meeting plane of commissure between right and straight angle, normally a small obtuse angle; pseudodeltidium with broad arch, normally lacking median groove; perideltidium reaching about half way to hinge ends.

Brachial valve normally flatly and evenly convex, rarely strongly convex, sulcus shallow and narrow when present.

Pedicle valve interior with large teeth, extending posteriorly along underside of interarea and edges of delthyrium, meeting anterior to apex, or connected to median septum by outgrowth of shell

material, either condition producing a shallow chamber beneath pseudodeltidial arch for reception of cardinal process; median septum bladelike, height depending upon depth of valve, apical end in most shells joined to dental ridges, upper edge making angle more obtuse in shallower valves, near right angle in deeper valves. Muscle area as long as median septum, occupying from one-third to about one-half total length of valve, may be impressed, slightly raised or outlined by raised border; muscle marks normally faint, anteriorly expanding grooves separated from one another by narrow ridges. Floor of valve weakly costellate, edges more strongly costellate.

Brachial valve interior with short straight cardi-

nal process, shallow, bifurcate at free end, each lobe longitudinally slit, with serrations within slits; dentifers fused to cardinal process, projecting bluntly forward, supported by erismata that diverge widely into umbonal arch in some valves, recurving toward hinge in others. Chilidium well developed, bisected by continuation of median groove of cardinal process. Muscle area in umbonal arch, posterolaterally bounded by cardinal process and short crural plates, occupying about one-third to one-half length of shell; muscle marks faintly impressed, normally separated into 2 groups by low median ridge. Valve floor faintly costellate, edges more strongly costellate.

MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 706b          |                                     |                                      |                          |                        |                             |                  |
| 151154a            | 9.2                                 | ?                                    | 9.6                      | 7.5                    | 3.4                         | 3.9              |
| 151154b            | 18.2                                | ?                                    | 20.2                     | 14.3                   | 8.0                         | 7.9              |
| 151154c            | 22.0                                | ?                                    | 26.2                     | 17.8                   | 5.9                         | 6.1              |
| 151154d            | 24.6                                | ?                                    | 28.4                     | 18.6                   | 6.8                         | 6.1              |
| 151154e            | 34.2                                | ?                                    | 39.8                     | 27.6                   | 10.0                        | 9.4              |
| 151154f            | 16.9                                | 14.6                                 | 20.4                     | 17.0                   | 4.3                         | 6.4              |
| 151154g            | ?                                   | 12.6                                 | 16.7                     | 11.5                   | ?                           | 4.0              |
| 151154h            | ?                                   | 21.8                                 | 28.4                     | 26.4                   | ?                           | 8.4              |
| 151154i            | ?                                   | 24.0                                 | 31.1                     | 22.0                   | ?                           | 7.9              |
| 151154j            | ?                                   | 29.4                                 | 38.9                     | 31.0                   | ?                           | 9.0              |
| 151154k            | ?                                   | 29.3                                 | 37.8                     | 34.9                   | ?                           | 8.6              |
| USNM 706           |                                     |                                      |                          |                        |                             |                  |
| 151152a            | 15.0                                | ?                                    | 20.4                     | 15.4                   | 3.4                         | 4.5              |
| 151152b            | 36.3                                | ?                                    | 44.0                     | 32.3                   | 8.7                         | 8.8              |
| USNM 706e          |                                     |                                      |                          |                        |                             |                  |
| 151158a            | 21.4                                | ?                                    | 27.4                     | 20.3                   | 6.2                         | 7.8              |
| 151158b            | 27.2                                | ?                                    | 33.8                     | 22.5                   | 6.8                         | 12.6             |
| USNM 706d          |                                     |                                      |                          |                        |                             |                  |
| 151151a            | 47.0                                | ?                                    | 55.4                     | 51.0*                  | 7.5                         | ?                |
| 151151b            | 62.5                                | ?                                    | 90.0?                    | 86.0?                  | 14.8                        | ?                |
| USNM 706e          |                                     |                                      |                          |                        |                             |                  |
| 153290c (holotype) | 32.0                                | ?                                    | 39.6                     | 28.9                   | 9.6                         | ?                |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank, Willis Ranch, and Appel Ranch members; lens between the last two members), Cherry Canyon Formation (Getaway Member).

LOCALITIES.—Road Canyon: USNM 703d, 706f, 716x; China Tank: USNM 706c, 713, 732s, 733q; Willis Ranch: AMNH 505, 506, USNM 706, 706b, 706e, 723t, 723w, 724u; Appel Ranch: USNM 704,

706d, 714o, 715i, 719z, 722t, 726t; Getaway: AMNH 512, USNM 728, 730, 732.

TYPES.—Holotype: USNM 153290c; figured paratypes: 151154f, j, l, m, o, 151165a, b, 153288, 153291; measured paratypes: 151154a–k, 151152a, b, 151158a, b, 151151a, b; unfigured paratypes: 151154a–e, g–i, k, n, 153290a, b; figured specimen: 153288.

COMPARISON.—*Derbyia filosa* is characterized by

its flatly convex pedicle valve, strong relatively uncrowded costellae that may be weakly crenulate, normally auriculate hinge, and especially by short bar or plates that join the median septum to the dental ridges, in all but a few shells. It most closely resembles the other coarsely costellate species from the Glass Mountains: *D. crenulata* Girty, *D. laqueata*, and *D. texta*, new species. Stronger costellae that are strongly crenulate, a lower interarea, and thicker shell wall distinguish *D. crenulata*. *Derbyia laqueata* has strong growth laminae, a narrower hinge, and normally is much more convex. *Derbyia texta* has a plicate pedicle valve, thick walls, webbed ornamentation on the brachial valve, and internally it has the median septum entirely separate from

the dental ridges. Other Glass Mountains *Derbyia* are not similar to *D. filosa* and can be distinguished by a variety of features, primary among which is their finer and more closely crowded costellation.

DISCUSSION.—*Derbyia filosa* varies in the convexity of both its valves, the proportional width of the hinge, the angle of posterior projection of the interarea, the height of the interarea, and in the number and strength of its costellae. Most shells have slight auriculation of the hinge ends, but some are nonauriculate. Most shells are somewhat distorted, but they are not truly irregular like *D. pannucia*, new species. The following tabulation illustrates the variation in number of costellae per 5 mm in shells from the two localities:

|                          |  |                                    |    |    |    |    |    |    |       |
|--------------------------|--|------------------------------------|----|----|----|----|----|----|-------|
|                          |  | <i>pedicle valves</i> (USNM 706)   |    |    |    |    |    |    |       |
| number of costellae/5 mm |  | 10                                 | 11 | 12 | 13 | 14 | 15 | 16 |       |
| number of specimens      |  | 3                                  | 6  | 7  | 6  | 4  | 3  | 1  |       |
|                          |  | <i>brachial valves</i> (USNM 706)  |    |    |    |    |    |    |       |
| number of costellae/5 mm |  | 11                                 | 12 | 13 | 14 | 15 | 16 | 18 | 19 20 |
| number of specimens      |  | 1                                  | 3  | 4  | 5  | 5  | 4  | 2  | 2 1   |
|                          |  | <i>pedicle valves</i> (USNM 706b)  |    |    |    |    |    |    |       |
| number of costellae/5 mm |  | 11                                 | 12 | 13 | 14 | 15 | 16 |    |       |
| number of specimens      |  | 4                                  | 7  | 8  | 12 | 10 | 4  |    |       |
|                          |  | <i>brachial valves</i> (USNM 706b) |    |    |    |    |    |    |       |
| number of costellae/5 mm |  | 12                                 | 13 | 14 | 15 | 16 | 17 | 18 | 19 20 |
| number of specimens      |  | 3                                  | 4  | 6  | 9  | 10 | 7  | 3  | 2 1   |

### *Derbyia informis*, new species

PLATE 76: FIGURES 1-8; PLATE 77: FIGURES 1-12; PLATE 78: FIGURES 1-20; PLATE 81: FIGURES 1-3

Large, strongly biconvex, surface irregular; strong discontinuous concentric undulations, radial folds, or combinations producing bumps and nodes; outline transversely subelliptical to nearly semi-circular; hinge from about half as wide to nearly as wide as maximum width of shell, normally auriculate; commissure wavy and irregular, but without consistent folds. Costellae fine, weak, closely crowded, may be finely crenulate, numbering on pedicle valve between 16 and 24, in 5 mm, averaging 18; on brachial valve between 17 and 26, averaging 21; growth lines moderately strong, becoming laminae near margins.

Pedicle valve irregularly convex, anterior profile convex, rarely nearly flat; interarea wide, moderately high, edges uneven, normally flat, but may be

concave or rarely convex; meeting of commissure near right angle; arch of pseudodeltidium narrow, low, straight sided or slightly expanding anteriorly, normally with shallow median groove or median flattening; perideltidium wide, edges more than half way from median line to hinge ends.

Brachial valve irregularly convex in lateral profile, broadly and depressed convex in anterior profile, normally not as bumpy and irregular as pedicle valve, beak may overhang slightly; nonsulcate.

Pedicle valve interior with strong teeth projecting forward from underside of interarea, extending posteriorly along interior edges of delthyrium as convergent dental ridges, meeting at apex of valve; median septum normally high because valve is deep, upper edge forming sharp angle, closer to right angle in deeper valves, more obtuse in shallower specimens, apical end of valve attached to inside of pseudodeltidial arch for variable distance

anteriorly, normally free of dental ridges except at apex of valve, in some specimens septum cemented to dental ridges by callus that may partly bury dental ridges. Muscle area as long as median septum, occupying about half valve length, raised or slightly depressed, in some having raised borders; muscle marks elongate anteriorly expanding grooves separated by narrow raised divides on floor of muscle area, faint striae on median septum, roughly parallel to anterior edge of septum. Floor of valve finely and weakly costellate, costellae becoming stronger near margins.

Brachial valve interior with moderately long,

curved, deeply bifurcate cardinal process, each lobe with longitudinal slit along posterior edge, insides of slits finely serrate; dentifers fused to sides of process, forming laterally open hinge sockets, projecting bluntly anteriorly into body chamber; erismata continuous with dentifers, diverging into umbonal arch, outlining posterolateral margins of muscle area. Chilidium very small or absent. Muscle area broad, bilobate, bisected by low median ridge, muscle marks faint longitudinal striae, extending about one-third length of valve. Floor of valve irregular, finely and weakly costellate, costellae becoming stronger near margins.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 702           |                            |                             |                  |                |                     |           |
| 151056a            | 4.0                        | ?                           | 5.4              | 4.4            | 1.9                 | ?         |
| 151056b            | 7.9                        | 5.3                         | 7.3              | 6.8            | 4.0                 | 4.7       |
| USNM 702 (low)     |                            |                             |                  |                |                     |           |
| 151062             | 10.8                       | 9.5                         | 11.8             | 11.0           | 9.4                 | 13.0      |
| 151056c            | 13.9                       | 11.8                        | 13.9             | 11.0           | 5.0                 | 9.0       |
| USNM 702c          |                            |                             |                  |                |                     |           |
| 151059a            | 14.2                       | 14.5                        | 20.1             | 17.1           | 3.5                 | 9.0       |
| 151059b            | 24.2                       | 16.9                        | 23.0             | 17.9           | 8.4                 | 20.0      |
| 151059c            | 28.4                       | 24.5                        | 29.5             | 20.7           | 10.4                | 21.8      |
| 151059d            | 30.8                       | 29.6                        | 33.6             | 28.7           | 9.9                 | 18.9      |
| USNM 703a          |                            |                             |                  |                |                     |           |
| 151066a            | 30.5                       | 30.8                        | 41.1             | 34.0           | 10.0                | 20.7      |
| USNM 702un         |                            |                             |                  |                |                     |           |
| 151064             | 37.3                       | 37.1                        | 52.0             | 34.1           | 13.8                | 25.0      |
| USNM 702           |                            |                             |                  |                |                     |           |
| 151056b            | 45.7                       | 40.0                        | 45.0?            | 31.8           | 21.9                | 39.0      |
| 151056d            | 56.8                       | 45.3                        | 61.4             | 36.0           | 17.0?               | 36.3      |
| 151056e            | 57.0                       | 58.0                        | 58.6+            | 31.5           | 22.5                | 44.0      |
| USNM 703a          |                            |                             |                  |                |                     |           |
| 152606c (holotype) | 73.4                       | 63.7                        | 85.2             | 61.9           | 24.6                | 49.0      |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member), Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500, 500B, 500L, 500X, USNM 702, 702b, 702inst, 702low, 702un, 703b, 703bs, 721u, 723p, 726o, 726u, 714w, 732u; Road Canyon: AMNH 503, USNM 702c, 703, 703a, 703c, 703d, 707e, 708c, 709c, 721o, 721t, 721y, 724b, 724j, 726d.

DIAGNOSIS.—Large variable *Derbyia* with fine costellae.

TYPES.—Holotype: USNM 152606c; figured paratypes: 151055a, b, 151056e, 151059b, d, 151073a, c,

152607a, 153286a, b, 153292; unfigured paratypes: 151056a–d, 151059a, c–q, 151073b, 152607b.

COMPARISON.—*Derbyia informis* is characterized by its large maximum and average size, strong convexity of both valves, auriculate hinge, narrow pseudodeltidial arch with narrow groove, fine and weak costellae that are rather closely crowded, its very irregular, wrinkled pedicle valve and somewhat less irregular brachial valve, and its normally independent dental ridges and median septum. Its closest relative in the Glass Mountains is *D. pannucia*, new species, which may be a descendant. *Derbyia informis* differs in its more convex pedicle



valve, less irregular brachial valve, more auriculate hinge, less frequently buried dental ridges and median septum attachment, grooved pseudodeltidial arch, normally higher interarea, and weaker costellation. The density of costellae is about the same in the two species, and the differences enumerated above are subtle, commonly requiring several specimens for their identification. The median septum of *D. informis* is higher than that of *D. pannucia* because the pedicle valve is deeper and throughout species of *Derbyia* the height of the septum increases with depth of the pedicle valve. The length of the cardinal process normally depends on the height of interarea of the pedicle valve, but in *D. pannucia* this relationship does not hold consistently, and its cardinal process is commonly as long as that of *D. informis*.

*Derbyia informis* differs from *D. profunda*, new species, and *D. nasuta* Girty in its stronger convexity, lower interarea, great irregularity of shell, and finer costellae. In addition, the greater density of costellae distinguishes it from *D. profunda*.

This species attains a size as great as that of *D. grandis* Waagen, from the Salt Range of Pakistan. It is much more irregular than that species, as well as more convex in both valves and much more finely

and densely costellate. *Derbyia regularis* Waagen also attains large size, but it is more regular and undistorted even than is *D. grandis*, as its name implies.

Individuals of *D. cymbula* Hall and Clarke may resemble *D. informis* in their convex pedicle valves, and interareas that meet the plane of commissure at right angles. But, *D. informis* has finer and more closely spaced costellae, reaches larger size, has a typically longer and stronger cardinal process, narrower pseudodeltidial arch, is much more distorted, and the average specimen is more convex than the average *D. cymbula*.

DISCUSSION.—Variation in *Derbyia informis* is extreme. Specimens may have nearly undistorted brachial valves, although the pedicle valve of every specimen is distorted, and the brachial valve of most is somewhat irregular. The outline of most specimens is transverse, but a few specimens are elongate. Most individuals are strongly convex, and have a convex anterior profile of the pedicle valve; some are flatter, and have nearly a straight or rarely convex anterior profile. Costellae are fine and weak; they range in density as shown on the following tabulation:

| <i>pedicle valve, USNM 702, 703a</i>  |    |    |    |    |    |    |    |    |    |    |  |
|---------------------------------------|----|----|----|----|----|----|----|----|----|----|--|
| number of costellae/5 mm              | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |    |  |
| number of specimens                   | 4  | 5  | 11 | 10 | 9  | 3  | 0  | 0  | 1  |    |  |
| <i>brachial valve, USNM 702, 703a</i> |    |    |    |    |    |    |    |    |    |    |  |
| number of costellae/5 mm              | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |  |
| number of specimens                   | 5  | 5  | 7  | 9  | 8  | 7  | 5  | 6  | 3  | 2  |  |

Internally the median septum normally attaches directly to the inside of the pseudodeltidial arch, without callus cementing it to the dental ridges. This condition is due in part to the near right angle at which the interarea meets the plane of commissure. In those specimens where this angle is more obtuse, the ridges tend to be buried near their apical ends in callus that also obscures the attachment of the median septum.

### *Derbyia laqueata*, new species

PLATE 74: FIGURES 1–26; PLATE 75: FIGURES 1–9

Small to medium size, biconvex moderately thick walled, shallowly conical, some shells moderately distorted; outline slightly to moderately transverse,

subelliptical to nearly quadrate; hinge slightly narrower than widest part of shell, normally auriculate; commissure normally straight, with tendency for shallow sulcation in some shells. Costellae strong, high, sharp or rounded, weakly to strongly crenulate, many shells with stronger primary costellae on either valve, intertroughs wide, costellae uncrowded, numbering between 10 and 17 in 5 mm on pedicle valve, averaging about 13; between 12 and 18 on brachial valve, averaging 15; growth laminae strong, relatively closely and evenly spaced.

Pedicle valve flatly to moderately conical, anterior profile normally convex, but frequently nearly flat or concave; interarea short to moderately long, wide, flat, or concave, more rarely convex, meeting plane of commissure between right and straight

angle, normally small obtuse angle; pseudodeltidium with wide arch and shallow median groove; perideltidium wide, edges more than half distance from median groove to hinge ends.

Brachial valve flatly to strongly convex, maximum convexity anterior to beak, broadly convex in anterior profile; sulcus shallow when present.

Pedicle valve interior with large teeth projecting forward from underside of interarea, extending as convergent dental ridges beneath interarea, along edges of pseudodeltidium, normally meeting at apex of valve, and without addition of callus material, but with apical ends buried in callus in a few individuals; median septum bladelike, height depending on depth of valve, apical end normally attached to inside of pseudodeltidial arch, but attached to dental ridges by secondary plates or ridges of callus in some valves, thus forming shallow chamber, not a true camera; upper edge of septum bent at obtuse angle, straighter in shallower valves. Muscle area as long as median septum, occupying between one-third and one-half length of valve,

normally shallowly impressed, but with raised border in some; muscle marks shallow, separated by low longitudinal ridges on floor of valve, forming faint striae on sides of median septum. Floor of valve weakly costellate, costellae stronger near margins.

Brachial valve interior with short but strong, slightly curved cardinal process, shallowly bifurcate at free end, each lobe longitudinally slit, with insides of slits serrate; dentifers fused to sides of process, forming shallow open hinge sockets; slightly and bluntly projecting into body chamber; erismata widely divergent into umbonal cavity, outlining posterolateral margins of muscle area. Chilidium well developed, bisected by continuation of median groove of cardinal process. Muscle area nearly circular, lightly impressed, muscle marks consisting of faint longitudinal or slightly radial striae, occupying about one-third of length of valve, bisected in some by low median ridge. Floor of valve faintly costellate, costellae stronger near margins.

#### MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 702c          |                                     |                                      |                          |                        |                             |                  |
| 151080a            | 3.5                                 | 3.7                                  | 4.7                      | 3.4                    | 2.0                         | 2.4              |
| 151080b            | 4.9                                 | 4.7                                  | 6.9                      | 5.9                    | 1.5                         | 2.9              |
| 151080c            | 6.4                                 | 6.6                                  | 7.4                      | 6.7                    | 3.6                         | 4.9              |
| 151080d            | 14.7                                | 14.4                                 | 17.7                     | 16.7                   | 5.0                         | 13.1             |
| 151080e            | 15.2                                | 13.5                                 | 20.0                     | 19.9                   | 5.5                         | 11.1             |
| 151076b            | 21.0                                | 15.8                                 | 21.7                     | 20.9                   | 6.0                         | 13.0             |
| 151080f            | 21.0                                | 18.9                                 | 20.7                     | 17.5                   | 10.0                        | 15.8             |
| 151080g            | 23.8                                | 23.8                                 | 32.9                     | 32.0                   | 6.0                         | 15.7             |
| 151080h            | 29.9                                | 28.4                                 | 39.2                     | 44.5                   | 6.5                         | 21.6             |
| USNM 703a          |                                     |                                      |                          |                        |                             |                  |
| 151090a            | 10.6                                | 9.7                                  | 13.7                     | 12.0                   | 6.6                         | 8.0              |
| 151090b            | 22.8                                | 21.6                                 | 29.9                     | 25.5                   | 6.8                         | 12.4             |
| 151090c (holotype) | 30.0                                | 27.3                                 | 40.0                     | 34.6                   | 7.4                         | 15.3             |
| 151090d            | 34.0                                | 34.0                                 | 43.0                     | 41.0                   | 12.5                        | 27.4             |
| USNM 702           |                                     |                                      |                          |                        |                             |                  |
| 151076a            | 11.4                                | 10.0                                 | 15.2                     | 14.4                   | 6.9                         | 11.5             |
| USNM 702un         |                                     |                                      |                          |                        |                             |                  |
| 151087             | 47.0                                | 39.5                                 | 58.4                     | 45.0                   | 9.7                         | 27.0             |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500, 500A, 500B, 500F, 500H, 500J, 500K, 500L, 500M, 500N, 500Q, 500X, 501, 509; USNM 702, 702a, 702b, 702ent, 702inst, 702-low, 702un, 703a<sup>1</sup>, 703b, 703bs,

708, 714w, 717e, 721u, 723u, 726o, 726u, 733m; Road Canyon: USNM 700v, 702c, 703, 703a, 703c, 703d, 707e, 709c, 710u, 716x, 716xa, 719x, 720d, 721j, 721r, 721t, 721w, 721x, 721y, 722f, 722v, 723o, 723x, 724b, 724c, 726e, 726f, 726x, 726z.

DIAGNOSIS.—Crenulate *Derbyia* of moderate size,

with fairly long interarea and median septum not joining dental ridges.

**TYPES.**—Holotype: USNM 151090c; figured paratypes: 151080j, k, 151086a, b, 151087, 153293, 153294a, b, c, 153295, 153296; measured paratypes: 151076a, b, 151080a–h, 151090a, b, d, 151087; unfigured paratypes: 151080a–h.

**COMPARISON.**—*Derbyia laqueata* is characterized by moderate size, strong and normally sharp crenulate costellae, strong shingle-like growth laminae, auriculate hinge, and commonly separate median septum and dental ridges. This species closely resembles *D. crenulata* Girty and may be descended from it. *Derbyia laqueata* differs in its sharper and more angular aspect, greater thickness, and longer (average) interarea, and primarily by its sharper, finer, more closely crowded costellae, and median septum that normally is not braced against the dental ridges by any callus.

Other species like *D. laqueata* found in the Glass Mountains are: *D. filosa*, new species, and *D. texta*, new species. The latter has a thicker shell, normally plicate pedicle valve, and fewer costellae per unit distance. *Derbyia filosa* attains larger size, normally is flatter, has the median septum joined to the dental ridges by pseudodental plates, and also has less dense costellae. Neither of these species has costellae that normally are as high, sharp, and strongly crenulate as those of *D. laqueata*.

All other species of *Derbyia* from the Glass Mountains differ strongly from *D. laqueata* and are not likely to be confused with it. A Pennsylvanian species from Texas, *D. ciscoensis* Dunbar and Condra (1932:104, pl. 10: figs. 6–8), is somewhat similar in shape to *D. laqueata*. Differences are the more auriculate hinge, more strongly convex brachial valve, and especially the finer, noncrenulate costellae. According to Dunbar and Condra (1932:103), *D. multistriata* (Meek and Hayden) from Early Permian Fort Riley Formation of Kansas resembles *D. ciscoensis*, but it differs from *D. laqueata* in most of the same features.

**DISCUSSION.**—*Derbyia laqueata* is one of the most variable and least unified of the Glass Mountain species of *Derbyia*. No single feature distinguishes it or differentiates it from all other species. Apparently it is intermediate between some of the more consistent and well-characterized species that occur above and below its range. Its interarea is some-

what longer than is normal in *D. crenulata* (Girty), but many individuals have proportionately short interareas. The median septum is typically free of the dental ridges, but in some specimens callus material unites them as in *D. crenulata* or *D. filosa*. Many specimens have brachial valves with strong primary costellae that, with the strong growth laminae, produce an interfering ornamentation approaching the webbed pattern of *D. texta*, but these are not accompanied by plicated pedicle valves. The number of costellae in 5 mm is close to that of all the other stronger costellate species, and their distributional patterns overlap, as comparison of the following tabulation with those for other species shows:

|                          |  |                                   |    |    |    |    |    |
|--------------------------|--|-----------------------------------|----|----|----|----|----|
|                          |  | <i>pedicle valve</i> (USNM 703a)  |    |    |    |    |    |
| number of costellae/5 mm |  | 11                                | 12 | 13 | 14 | 15 |    |
| number of specimens      |  | 3                                 | 7  | 9  | 7  | 4  |    |
|                          |  | <i>brachial valve</i> (USNM 703a) |    |    |    |    |    |
| number of costellae/5 mm |  | 12                                | 13 | 14 | 15 | 16 | 17 |
| number of specimens      |  | 2                                 | 4  | 6  | 6  | 7  | 2  |
|                          |  | <i>pedicle valve</i> (USNM 702)   |    |    |    |    |    |
| number of costellae/5 mm |  | 11                                | 12 | 13 | 14 | 15 | 16 |
| number of specimens      |  | 7                                 | 8  | 8  | 6  | 4  | 0  |
|                          |  | <i>brachial valve</i> (USNM 702)  |    |    |    |    |    |
| number of costellae/5 mm |  | 12                                | 13 | 14 | 15 | 16 | 17 |
| number of specimens      |  | 4                                 | 6  | 8  | 8  | 3  | 2  |

### *Derbyia nasuta* Girty

PLATE 70: FIGURES 1–11; PLATE 71: FIGURES 1–9; PLATE 72: FIGURES 1–12; PLATE 73: FIGURES 1–18; PLATE 89: FIGURES 14–23

*Derbyia nasuta* Girty, 1909:182, pl. 26: figs. 6–6c.—?R. E. King, 1931:59, pl. 8: figs. 1–2.

Not *Derbyia nasuta* Girty.—McKee, 1938:225, pl. 44: figs. 1–2.

Usually very large, thin walled, biconvex, moderately to deeply conical, somewhat distorted by attachment, normally concentrically undulating, some subtly plicate; outline transversely subelliptical; hinge half to nearly as wide as greatest shell width, some specimens slightly auriculate; commissure even, nonsinuate, except for wave near hinge in some shells. Costellae low, fine, even, rarely alternating, added by insertion, rarely weakly crenulate, with narrow intertroughs, more crowded anteriorly.

Pedicle valve usually deeply conical, narrowly to broadly expanding, anterior profile slightly to

strongly convex; interarea short to very long, concave or flat, rarely convex, meeting plane of commissure at nearly right angle; pseudodeltidium with narrow arch with or without median groove; perideltidium spreading on each side to about half distance between midline and hinge end.

Brachial valve flatly, evenly convex except for slightly more convex beak. Anterior profile broadly and gently convex; umbonal region swollen; antero-median region flattened, not sulcate.

Pedicle valve interior with large teeth, converging posteriorly beneath edges of delthyrium as dental ridges, meeting at apex of valve; median septum high, bladeliike, free edge bent at right angle, apical end joining directly to underside of pseudodeltidial arch completely independent of dental ridges. Muscle area as long as median septum, bisected by it, occupying slightly less to slightly more than half length of valve, muscle marks faint longitudinal ridges and depressions in

muscle area and on sides of median septum. Floor of valve with moderately strong costellae becoming slightly stronger toward margins.

Brachial valve interior with cardinal process long (corresponding to normally long interarea of pedicle valve), very strong, bifid; notch between lobes exceptionally deep, each lobe longitudinally slit throughout its length, insides of slits minutely serrate; dentifers firmly cemented to sides of process, projecting anteriorly into chamber of valve, forming shallow, open hinge sockets; erismata high, strong, widely divergent, extending into umbonal arch of valve, around posterolateral margins of muscle area. Chilidium small, bilobed, remnantal, or absent; narrow ginglymus along hinge edge. Muscle area bilobate, muscle marks well impressed, shallow, longitudinal grooves with narrow separating ridges; floor of valve with fine costellae that become slightly stronger near margins.

#### MEASUREMENTS (in mm).—

|           | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|-----------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 707a |                                     |                                      |                          |                        |                             |                  |
| 151030a   | 25.0                                | 16.0                                 | 19.0                     | 16.8                   | 10.8                        | 17.5             |
| 151030b   | 44.6                                | 32.2                                 | 39.7                     | 34.6                   | 24.0?                       | 37.8             |
| 151030c   | 40.4                                | 40.4                                 | 55.5                     | 43.0                   | 29.5?                       | 42.0             |
| 151030d   | 56.3                                | 54.0                                 | 58.4                     | 41.7                   | 37.9                        | 61.2             |
| 151030e   | 62.0                                | 51.8                                 | 66.0                     | 44.6?                  | 37.4                        | 61.8             |
| 151030f   | 76.3                                | 65.5                                 | 74.0?                    | 43.0                   | 26.7                        | 63.0             |
| 151030g   | 74.2                                | 74.2                                 | 76.4                     | 58.0                   | 36.5                        | 58.7             |
| 151030h   | 75.8                                | 70.6                                 | 87.4                     | 58.9                   | 21.3                        | 52.8             |
| 151030i   | 67.7                                | 44.8                                 | 37.8                     | 27.2?                  | 40.7                        | 56.0             |
| 151030j   | 80.3                                | 64.0                                 | 59.6                     | 36.8                   | 37.0                        | 58.0             |
| 151030k   | 4.6                                 | 3.9                                  | 5.0                      | 4.4                    | 2.7                         | 2.6              |
| 151030-l  | 5.2                                 | 5.0                                  | 6.2                      | 4.7                    | 3.5                         | 3.3              |
| 151030m   | 8.8                                 | 7.5                                  | 10.5                     | 9.2                    | 6.0                         | 5.5              |
| USNM 720e |                                     |                                      |                          |                        |                             |                  |
| 151038h   | 57.5                                | 56.6                                 | 75.6                     | 48.8                   | 25.3                        | 48.0             |

STRATIGRAPHIC OCCURRENCE.—Basal Bone Spring Formation, Skinner Ranch Formation (Decie Ranch Member, Sullivan Peak Member), Cibolo Formation (Breccia Beds).

LOCALITIES.—Bone Spring: AMNH 625, 628, 629, 631, 696, 699, USNM 725c, 728e, 728f; Decie Ranch: USNM 707a, 707w, 707z, 708q, 709w, 714t, 715v; Sullivan Peak: USNM 707d, 707, 722-1, 733j; Skinner Ranch: USNM 714p, 716t, 723s, 724p; Lower Skinner Ranch: USNM 705a, 720e; Cibolo: AMNH 703, USMN 738r.

DIAGNOSIS.—Very large *Derbyia* with fine ornament and usually long interarea.

TYPES.—Figured hypotypes: USNM 151029, 151030e, h, i, 151038a, c-f, g-j, 153297a, b, 153298, 153299, 153547a-c; unfigured measured hypotypes: 151030a-d, f, g, j-m.

COMPARISON.—*Derbyia nasuta* is characterized by its large average and maximum size, fine and closely spaced costellae that normally are nearly equal in strength, but without conspicuous alternation, its normally deeply conical pedicle valve with attend-

ant long interarea, narrow pseudodeltidial arch, median septum that is independent of dental ridges, long, strong, and deeply notched cardinal process, and its weak or absent chilidium. It resembles *D. profunda*, new species, in its deep pedicle valve, but it differs in its larger size, proportionately narrower hinge, finer and more closely crowded costellae that normally are not crenulate, its narrower pseudodeltidial arch, independent median septum, and more rugose or undulating shell surface marked by more conspicuous laminae of growth. For a group of specimens in hand, the sure diagnostic distinction is the greater average number of costellae per unit space.

A related species is *D. pannucia*, new species, from the Word Formation. *Derbyia nasuta* has a deeper pedicle valve, an interarea that meets the plane of commissure at more nearly a right angle, normally flatter brachial valve, and much more regular, less bumpy, and less deformed shell. Many individuals of *D. pannucia* have the median septum independent of the dental ridges, as in *D. nasuta*, but most have the septum cemented to the ridges by deposits of shell material near the apex of the pedicle valve.

DISCUSSION.—*Derbyia nasuta* Girty is not highly variable in its specific characters. The nasute pedicle valve is distinctive, and only a few individuals have the atypical short interarea: these are unusually inflated and obese individuals. The pseudodeltidial arch, which is typically narrow, may be wide in some individuals, and may possess a median groove, indistinguishable from that of *D. profunda*. We have seen no specimen in which the median septum of the pedicle valve is cemented to the

dental ridges or in which the space between the ridges and the septum is filled.

This species is preserved most abundantly as calcareous steinkerns or calcite-filled, partly silicified shells. Only about 50 specimens in the national collections have been freed by treatment in acid and show features of the interior. The calcareous specimens have the characteristic shape that is typical of the species and can be identified on that basis, as well as on the basis of their association with a few relatively complete and free shells.

Apparently Girty (1909:182) based this species on a single specimen, which now is fragmented very badly, especially the anterior parts, but, nevertheless, with all except the anterior of the brachial valve present. His description of the material is inaccurate in some details. He states that the ventral valve is “inclined backward so that the cardinal area makes a rather strongly obtuse angle with the plane of the edge.” To the contrary, King (1931:59) says that the interarea lies “at nearly right angles to the margin.” Our examination of the holotype, as well as of specimens in the national collection leads us to agree with King. Girty (1909:183) says that the “lirae number 8 to 11, usually 10 or 11, in 5 mm,” and King (1931:59) counted “10 to 14 in the space of 5 mm., varying on different specimens.” We count 12 in 5 mm on the pedicle valve and 18 on the brachial. These discrepancies of *D. nasuta* probably arise from the fragmentary condition of the holotype, but we now have a sufficiently large collection to compose a reliable description of the species, not just of the holotype specimen.

A count of the number of costellae in 5 mm on some shells from USNM 705a gave the following results:

|                          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|--------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| number of costellae/5 mm | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| number of specimens      | 1  | 1  | 3  | 2  | 3  | 7  | 4  | 4  | 3  | 2  | 1  | 1  | 2  | 0  | 0  | 1  |

The holotype of *D. nasuta* is from Girty's (1909: 512) station 3764, which is said to be north of the Hazel Mine in the Sierra Diablo. Several other species that are based on material from station 3764, such as *Meekella attenuata* Girty, *Enteleles dumblei* Girty, and *Derbyia crenulata* Girty, are identical with, or closely related to, species that occur in the fauna of the Decie Ranch Member of the Glass Mountains rather than in the Leonardian

as postulated by Girty (1909:295, ftn. a) or by Stehli (1954:268).

*Derbyia pannucia*, new species

PLATE 68: FIGURES 1-3; PLATE 83: FIGURES 1-12; PLATE 84: FIGURES 1-8; PLATE 85: FIGURES 1-7; PLATE 86: FIGURES 1-11

Large, moderately thick walled, flatly to moderately biconvex, normally irregular, shape modified



by attachment or spontaneously deformed; outline transversely subelliptical to nearly semicircular; hinge from about three-fourths as wide as, to slightly wider than, midwidth, slightly auriculate or not; commissure without consistent sinuities, very irregular and wavy in detail; either or both valves irregularly radially plicate, and/or concentrically rugose, in erratic patterns, rarely relatively smooth and free of distortion. Costellae fine, weak to moderately strong, rounded, some slightly crenulate or bumpy, maintaining strength to margins, equal in strength, or with slightly stronger primary costellae, increase by insertion; number on pedicle valve between 15 and 30 in 5 mm, average 21; growth laminae moderately well developed.

Pedicle valve flattish to strongly convex; anterior profile may be concave, nearly flat, convex, or flexed; interarea wide, low to moderately high, edges irregular, meets plane of commissure at obtuse (apsacline) or nearly right angle, normally flat, less commonly concave, rarely convex; pseudodeltidium with narrow arch, either high and ridge-like, or nearly flattened, without median groove; perideltidium wide, spreading nearly to edge of interarea at hinge, not necessarily parallel to edge of interarea.

Brachial valve moderately to strongly convex, may have strongly overhanging beak.

Pedicle valve interior with hinge teeth projecting forward from underside of interarea, extending posteriorly along edges of pseudodeltidium as con-

vergent dental ridges, meeting at, or slightly anterior to, apex of valve; median septum low to moderately high, depending upon depth of valve, upper surface flexed nearer right angle in deeper valves, at large obtuse angle in flatter valves; apical end of septum may be independent of dental ridges, more commonly cemented to ridges by callus shell material that may partly bury apical ends of ridges and septum, none with true camera. Muscle area as long as median septum, occupying normally about half, but exceptionally up to three-fourths of total length of shell, raised or thickened in many shells, many with edges bounded by thickening; muscle marks elongate shallow grooves separated by narrow ridges on floor of valve, faint striae on sides of median septum. Floor of valve irregular, faintly costellate, with stronger radial costellae near edges.

Brachial valve interior with strong, long, curved cardinal process, bifid, deeply notched, with widely divergent prongs, each longitudinally slit along posterior edge, insides of slits finely serrate; dentifers fused to sides of process, projecting bluntly into chamber of valve; hinge sockets open posteriorly and laterally; erismata strong, high, diverging into umbonal cavity, outlining posterolateral margins of muscle area. Chilidium not present. Muscle area bilobate, bisected by low median ridge, occupying about one-third of length of valve, beneath arch of cardinalia. Floor of valve irregular, may be faintly costellate, with slightly stronger radial costellae at margins.

## MEASUREMENTS (in mm).—

|                   | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 706e         |                            |                             |                  |                |                     |           |
| 151122a           | 5.0                        | ?                           | 5.6              | 4.4            | 1.6                 | ?         |
| 151122b           | 5.7                        | ?                           | 7.0              | 6.0            | 2.6                 | ?         |
| 151122c           | 10.5                       | ?                           | 9.4              | 7.7            | 4.0                 | ?         |
| 151122d           | 15.6                       | ?                           | 15.8             | 12.5           | 6.0                 | ?         |
| 151122e           | 19.4                       | ?                           | 17.3             | 16.8           | 7.8                 | ?         |
| 151122f           | 20.6                       | ?                           | 27.6             | 21.0           | 6.0                 | ?         |
| 151122g           | 23.0                       | ?                           | 27.1             | 23.6           | 14.3                | ?         |
| 151122h           | 32.8                       | ?                           | 35.7             | 24.2           | 9.5                 | ?         |
| 151122i           | 39.8                       | ?                           | 40.3             | 32.5           | 15.8                | ?         |
| 151122j           | 37.0                       | ?                           | 50.6             | 47.3           | 15.5                | ?         |
| 151122k           | 50.5                       | ?                           | 80.7             | 59.7           | 15.5                | ?         |
| 151122-l          | 76.2                       | ?                           | 89.5             | 62.6           | 24.5                | ?         |
| 151122m           | 64.6                       | ?                           | 94.8             | 66.6           | 18.6                | ?         |
| 151122n           | 67.0                       | ?                           | 87.9             | 77.0           | 22.0                | ?         |
| 151122o           | 59.0                       | 55.6                        | 76.0             | 51.9           | 13.8                | 35.5      |
| USNM 706c         |                            |                             |                  |                |                     |           |
| 151119a           | 49.0                       | ?                           | 64.6             | 48.8           | 23.7                | ?         |
| USNM 706b         |                            |                             |                  |                |                     |           |
| 153346 (holotype) | 72.2                       | 68.8                        | 85.0             | 7.4            | 56.7                | 55.0      |

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, Appel Ranch members and lens between last two), Cherry Canyon Formation (Getaway Member).

LOCALITIES.—China Tank: USNM 706c, 713, 726r, 733q; Willis Ranch: AMNH 506, USNM 706, 706e, 718d, 723t, 724u; lens: USNM 706b; Appel Ranch: USNM 706d, 714o, 715i, 719z, 722t, 727j; Getaway: AMNH 512, 600, USNM 728, 730, 732.

DIAGNOSIS.—Very large *Derbyia* with strong, irregular wrinkling and no chilidium.

TYPES.—Holotype: USNM 153346; figured paratypes: USNM 151115, 151117, 151119b, 151121a–f, 151122e, g, k, m, n, p, q, r; measured paratypes: 151122a–o, 151119a; unfigured paratypes: 151119a.

COMPARISON.—Relatively irregular specimens of *Derbyia cymbula* Hall and Clarke bear superficial resemblance to relatively regular individuals of *D. pannucia*. In the former, however, the irregularity is confined mostly to the pedicle valve, whereas both valves of *D. pannucia* are wrinkled. Furthermore, the costellae of *D. cymbula* are more widely spaced, the pseudodeltidial arch is wide, a well-developed chilidium is present, and the cardinal process is comparatively short and weak. *Derbyia grandis* Waagen attains a size comparable to that of *D. pannucia*, but the Salt Range species has sharper, coarser, and more widely spaced costellae,

wider pseudodeltidial arch, and narrower perideltidium. Apparently a chilidium is present in *D. grandis*, although Waagen's (1884, pl. 51–53) illustrations do not show it clearly, and it is not well preserved on the specimens in the national collection (USNM).

DISCUSSION.—*Derbyia pannucia* is the most variable of the Glass Mountain species of *Derbyia*. The pedicle valve may be deep and convex, although it normally is shallow and rather flat, the hinge may be sufficiently narrow to make the outline of the shell oval, or it may be the widest part of the shell, even slightly auriculate. Wrinkling of the surface is weak in some specimens, normally is strong, but the pattern is not regular: in some it consists of dominantly radial plications; in others, of dominantly concentric rugae; in others, of discontinuous bumps and nodes; in others, of connected bumps produced by interfering radial and concentric wrinkles. The narrow pseudodeltidial arch, which is considered to be characteristic of the species, is rather wide on many juvenile shells, near the beak of some mature shells, and may bear a distinct median groove at that stage.

Internally, the dental ridges and median septum normally remain unconnected, but in many individuals the ridges are buried in callus, connecting them to the septum, and in some the ridges ap-

pear to converge on the septum anterior to the apex of the valve. The cardinal process is large and strong, a reliable and consistent feature of almost all specimens, but a few have that structure comparatively short and weak.

The number of costellae per 5 mm varies within the figures mentioned in the description of the species. The following tables show the pattern of distribution:

|                          |  |                                    |    |    |    |    |    |    |                |
|--------------------------|--|------------------------------------|----|----|----|----|----|----|----------------|
|                          |  | <i>pedicle valves (USNM 706)</i>   |    |    |    |    |    |    |                |
| number of costellae/5 mm |  | 17                                 | 18 | 19 | 20 | 21 | 22 | 23 |                |
| number of specimens      |  | 1                                  | 9  | 7  | 4  | 3  | 2  | 4  |                |
|                          |  | <i>brachial valves (USNM 706)</i>  |    |    |    |    |    |    |                |
| number of costellae/5 mm |  | 17                                 | 18 | 19 | 20 | 21 | 22 | 23 | 24 25 26 27 28 |
| number of specimens      |  | 1                                  | 0  | 3  | 4  | 5  | 5  | 4  | 2 2 2 1 1      |
|                          |  | <i>pedicle valves (USNM 706b)</i>  |    |    |    |    |    |    |                |
| number of costellae/5 mm |  | 14                                 | 15 | 16 | 17 | 18 | 19 | 20 | 21 22          |
| number of specimens      |  | 1                                  | 3  | 9  | 8  | 6  | 4  | 2  | 2 1            |
|                          |  | <i>brachial valves (USNM 706b)</i> |    |    |    |    |    |    |                |
| number of costellae/5 mm |  | 16                                 | 17 | 18 | 19 | 20 | 21 | 22 | 23 24 25 26 27 |
| number of specimens      |  | 2                                  | 4  | 8  | 6  | 11 | 10 | 6  | 3 2 2 1 1      |

Derbyia profunda, new species

PLATE 67: FIGURES 1-27; PLATE 68: FIGURES 4-11

Derbyia cymbula Hall and Clarke, 1892:398, pl. 11B: figs. 2, 3.—R. E. King, 1931:59, pl. 8: figs. 3a, b.

Large, moderately thick walled, biconvex, moderately to deeply conical, shape modified by attachment but otherwise not greatly distorted; outline transversely subelliptical to semicircular; hinge slightly narrower than widest part, cardinal extremities usually obtuse, rarely auriculate; commissure broadly sulcate, with minor fortuitous contortions; incipient in some specimens. Psedodeltidium narrow, not strongly arched, and with a prominent impressed median groove. Costellae strong but fine, moderately high, sharp near beaks, becoming straight sided and blunt toward edges of shells, crowded together with narrow intertroughs, primary costellae slightly stronger, giving fairly regularly alternating pattern, increase by insertion, crenulation weak and obscure; costellae similar in shape on both valves, slightly less crowded on pedicle, numbering 10 to 18 in 5 mm, averaging 15, those on brachial valve numbering 12 to 21, averaging 16 in 5 mm; growth lines faint except near edges of shell, where several laminae may be present.

Pedicle valve moderately to deeply conical, broadly expanding, anterior profile normally convex, but more rarely nearly flat or concave; inter-

area high and wide, flat or concave, more rarely convex, meeting plane of commissure at nearly right angle or slanting posteriorly, rather evenly tapered to attenuate; pseudodeltidium with broad arch bisected by shallow groove; perideltidium slightly raised above lateral parts of interarea, spreading to about half distance between midline and hinge edge, not necessarily paralleling edge of interarea.

Brachial valve lidlike, unevenly and flatly to moderately convex longitudinally, with maximum convexity near beak; anterior profile nearly flat; anteromedian region usually flattened, not sulcate.

Pedicle valve interior with large teeth converging posteriorly along underside of delthyrial edges as dental ridges, meeting at apex of valves; median septum high, bladeliike, upper edge strongly angular longitudinally, obtuse in shallower valves with flat or concave profile, nearer right angle in deeper valves; anterior end of septum reaching anterior edge of muscle area, apical and variably attached, in some shells septum attached directly to underside of pseudodeltidial arch, remaining free of dental ridges, in others shell material filling space between septum and ridges, becoming drawn out anteriorly as pseudodental plates, many specimens with pseudodental plates continuing sufficiently far forward along septum and plates to form deep camera as edge of septum and inside of pseudodeltidial arch diverge; some specimens with only 1

such plate developed, clearly showing median septum free of arch except immediately anterior to apex of valve. Muscle area as long as median septum, normally slightly less than half valve length, not deeply impressed, and with faint muscle marks on sides of septum. Floor of valve with obscure costellae becoming slightly stronger near edges.

Brachial valve interior with moderately strong, normally long, slightly curved cardinal process (length dependent upon height of pedicle interarea), shortly bifurcate at free end, but longitudinally grooved throughout length, each lobe longitudinally slit, with insides of slits minutely

serrate; dentifers firmly cemented to sides of process, forming open hinge sockets, and projecting almost directly ventrally; erismata low, diverging into umbonal arch, outlining posterolateral parts of muscle area. Chilidium fairly prominent, not completely bisected by median groove of cardinal process; hinge with narrow bearing-surface (ginglymus) of uniform width, not tapering toward hinge ends; muscle area bilobate, ill defined, with faint longitudinal muscle marks; interior surface of valve faintly costellate, slightly more deeply marked near edges.

MEASUREMENTS (in mm).—

|                   | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701k         |                            |                             |                  |                |                     |           |
| 151015a           | 3.5                        | 3.0                         | 3.4              | 3.0            | 1.5                 | 2.2       |
| 151015b           | 5.6                        | 4.5                         | 6.0              | 4.6            | 3.0                 | 3.4       |
| 151015c           | 8.0                        | 6.4                         | 8.3              | 6.8            | 5.0                 | 6.0       |
| 151015d           | 10.2                       | 6.6                         | 10.4             | 9.5            | 5.4                 | 4.6       |
| 151015e           | 13.2                       | 11.6                        | 16.5             | 13.9           | 7.8                 | 10.9      |
| 151015f           | 18.5                       | 16.0                        | 23.4             | 19.0           | 10.9                | 15.0      |
| 151015g           | 22.2                       | 22.0                        | 24.7             | 19.7           | 14.4                | 23.9      |
| 151015h           | 23.9                       | 23.2                        | 32.9             | 27.9           | 11.6                | 21.3      |
| 151015i           | 38.5                       | 26.0                        | 36.6             | 28.0           | 13.3                | 19.6      |
| 151015j           | 44.2                       | 33.8                        | 45.3             | 37.2           | 22.0                | 27.5      |
| 151015k           | 52.0                       | 41.4                        | 49.0             | 41.0           | 21.4                | 32.9      |
| 151015-l          | 45.8                       | 41.6                        | 53.5             | 48.2           | 33.5                | 52.8      |
| 151015m           | 50.0                       | 47.0                        | 61.0             | 53.0           | 37.8                | 43.0      |
| 151015n           | 54.2                       | 54.6                        | 66.5             | 56.5           | 29.6                | 47.6      |
| 153348 (holotype) | 53.5                       | 48.3                        | 60.5             | 49.6           | 15.0                | 39.6      |

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 2–14), Lenox Hills Formation.

LOCALITIES.—*Uddenites*: USNM 701u, 713u; Neal Ranch: 701, 701a, 701a<sup>1</sup>, 701a<sup>3</sup>, 701c, 701d, 701g, 701h, 701k, 701-l, 712w, 715e, 721g; Lenox Hills: 705, 707j, 715.

DIAGNOSIS.—Large *Derbyia* with gently convex brachial valve, which has a flattened umbonal region.

TYPES.—Holotype: USNM 153348; figured paratypes: 151015c, e, g, j, 153347a–c, 153349; unfigured measured paratypes: 151015a, b, d, f, h, i, k–n.

COMPARISON.—*Derbyia profunda* is a very distinctive and easily recognized species characterized by its deep conical pedicle valve with narrow, grooved pseudodeltidial arch, relatively flat brachial

valve with well-developed chilidium, weakly crenulate costellae that are much lower than in *D. crenulata*, but average only 15 and 16 per 5 mm on the pedicle and brachial valves respectively. Internally the species is distinguished by its high median septum and strong dental ridges that may or may not attach to the septum by callus filling or pseudodental plates. The deep pedicle valve with high interarea, and the weaker costellae that number nearly the same in 5 mm, and the larger average size distinguish this species from *D. crenulata* Girty and *D. carteri*, new species. In addition, the hinge of *D. profunda* is not auriculate and, although wide, is not the widest part of the shell, and the cardinal extremities are usually obtuse. The only species that might be confused with *D. profunda* is *D. nasuta* Girty, which also has a high interarea and attains a larger size. That species differs in its

flatter pseudodeltidial arch, poorly developed or absent chilidium, noncrenulate costellae that average about 20 in 5 mm and that are all nearly uniform in strength, not alternating. No other American species of *Derbyia* has the large size, wide hinge, and long inetrarea of *D. profunda*.

Internally *D. profunda* is interesting because it contains individuals with the true *Derbyia*-like arrangement of the dental ridges (completely separate from the median septum), some with deep chambers formed by a plate from each dental ridge attaching to the top of the septum, and the septum remaining detached from the inside of the pseudodeltidium except at the apex. The latter condition is similar to the plate arrangement of *Orthotetes*. In addition, there are many intermediates of various kinds: some individuals have a plate uniting the top of the septum to only one of the dental ridges, others with the chamber between the top of the septum and the underside of the pseudodeltidial arch completely or partly filled with shell material, producing chambers of varying depth. This is not the only species in the Glass Mountains fauna that has individuals with secondary characters simulating those of *Orthotetes*.

### *Derbyia scitula*, new species

PLATE 73: FIGURES 19–32; PLATE 82: FIGURES 3–10

Small, strongly inequivalve, brachial valve much shallower than strongly conical pedicle valve; hinge narrow, usually auriculate, about three-fourths of maximum width, which is anterior to midvalve. Sides oblique to concave; anterolateral extremities narrowly rounded; anterior margin gently rounded, narrowly emarginate in some speci-

mens. Anterior commissure usually sulcate; lateral commissure straight to strongly convex in dorsad direction. Surface costellate, costellae subequal, tightly crowded on brachial valve, less so on pedicle valve, numbering 11–13 in 5 mm at 10 mm anterior to beak and 7–8 in 5 mm at anterior margin of large specimens on brachial valve and 1 or 2 less on pedicle valve.

Pedicle valve triangular in lateral profile, long side being nearly flat to unevenly concave; anterior profile irregular; interarea moderately long with well-marked perideltidial area occupying about half interarea on each side of pseudodeltidium, which is fairly broad and arched and often medially grooved. Beak usually deformed, which is over fairly broad surface in some specimens. Median region swollen to form ill-defined fold; flanks usually steep.

Brachial valve varying from moderately to strongly convex in lateral profile; anterior profile broadly and moderately convex and usually with a median depression. Umbonal region varying from nearly flat to moderately swollen; sulcus narrow, usually present, narrow, moderately rounded, giving valve bilobed appearance; sides short and moderately steep.

Pedicle valve interior with small teeth and low dental ridges; median septum delicate reaching about to midvalve, forming obtuse angle in lateral view and apically attached to the pseudodeltidium, not producing false dental plates and apical chamber. Muscles lightly impressed.

Brachial valve interior with strong, bilobed chilidium, short, slightly cleft myophore and short, widely divergent supporting plates. Muscles not strongly impressed.

### MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701           |                            |                             |                  |                |                     |           |
| 151202a (holotype) | 18.9                       | 18.9                        | 21.5             | 15.6           | 8.2                 | 16.9      |
| 151202b            | 14.2                       | 13.4                        | 16.0             | 12.0           | 7.5                 | 17.2      |
| 151202c            | 12.2                       | 11.8                        | 15.4             | 12.4           | 6.0                 | 11.4      |
| 151202d            | 13.0                       | 12.0                        | 12.8             | 9.4            | 4.9                 | 10.3      |
| 151202e            | 9.4                        | 8.8                         | 10.5             | 7.4            | 4.0                 | 7.7       |
| 151202f            | 6.4                        | 6.0                         | 7.6              | 6.0            | 4.0                 | 5.6       |
| 151202g            | 5.1                        | 5.0                         | 6.0              | 5.6            | 3.6                 | 4.0       |



STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of bed 2 of P. B. King).

LOCALITIES.—USNM 701, 701c, 701d.

DIAGNOSIS.—Small, thick strongly costellate *Derbyia* with sulcate brachial valve.

TYPES.—Holotype: USNM 151202a; figured paratypes: 151202d, h, 153289a, c, d, 153345; measured paratypes: 151202b–g; unfigured paratypes: 153289b.

COMPARISON.—No species from the Glass Mountains is like this one, but it is similar to *Derbyia bennetti* Hall and Clarke. Both have the same general form, that of a somewhat triangular outline with the anterior expanded somewhat laterally. The Permian species differs from the Pennsylvanian one in having somewhat stronger costellae near the beak, a less deep brachial valve, more even sulcation of the pedicle valve, and a generally smaller size.

DISCUSSION.—Possibly the true size of this species is fully exhibited by the material studied. The largest specimens measure about 25 mm in length and width, which may be the maximum size, but the large specimens are few. Attached forms are fixed by a large part of the ventral surface of the pedicle valve, but the majority of specimens have broken free of their moorings. Since no false dental plates were seen in any of the pedicle valves, no specimens have the orthotetid-like chamber noted in some species of *Derbyia*. In the brachial valve the supporting plates are widely divergent but variable, not having been very extended in some specimens.

### *Derbyia strophomenoidea*, new species

PLATE 69: FIGURES 1–9

Large, strophomenid in lateral profile, subrectangular in outline wider than long; hinge slightly less in width than midwidth; cardinal extremities approaching, or slightly greater than, right angle; sides gently rounded; anterior margin broadly rounded to subtruncate. Anterior commissure broadly sulcate; surface multicostellate, costellae more crowded on brachial valve than on opposite one; costellae numbering on brachial valve 11 in 5 mm at 10 mm anterior to beak, 9 in 5 mm at 20 mm anterior to beak and 7 at anterior margin; costellae on pedicle valve numbering 10 at 5 mm anterior to beak, 7 at 20 mm anterior to beak and 7 at anterior margin.

Pedicle valve in lateral profile convex in posterior half, but gently concave in anterior half; anterior profile gently concave. Interarea short, strongly apsacline and with wide perideltidial area. Median region gently swollen; flanks and anterior flattened.

Brachial valve moderately and evenly convex in lateral profile, but broadly and fairly strongly convex in anterior profile. Interarea extremely short; chilidium short. Umbonal region flatly convex, but median region well inflated but with long moderately steep slopes.

Pedicle valve interior with strong dental ridges and median septum welded to under side of pseudodeltidium; teeth long and slender. Length of septum not known.

Brachial valve interior with moderately long and thick cardinal process with lobes narrowly forked; dentifers short, slightly protuberant but supporting plates long and thick. Myophragm low but thick.

MEASUREMENTS (in mm).—Paratype (USNM 151215a): pedicle valve length 46, brachial valve length 42.5, maximum width 62.8, hinge width 52.0 plus, interarea length 13.8, thickness 19.2; holotype (USNM 151213b): pedicle valve length 56.0, brachial valve length 52.6, maximum width 59.4, hinge width 52.3, interarea length 14.0, thickness 25.0?

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (bed 4 of P. B. King).

LOCALITY.—USNM 701–1.

DIAGNOSIS.—Large slender *Derbyia* having a strophomenoid profile.

TYPES.—Holotype: USNM 151213b; figured paratype: 151213a.

COMPARISON.—This species differs from *D. profunda* in the compressed strophomenoid form, the shallow brachial valve, and the character of the ornament. *Derbyia wabaunseensis* Dunbar and Condra and *D. kansasensis* Dunbar and Condra are strophomenoid in form and resemble *D. strophomenoidea*. The former is smaller, with a narrower hinge and shorter interarea than the Neal Ranch species. *Derbyia kansasensis* is a square species, with a less concave pedicle valve than the Glass Mountains species. These comparisons are based on few specimens.

DISCUSSION.—This is a rare species and has been

seen only at USNM 701-1. The large paratype shows the two valves in contact from the inside and makes clear the role of the socket ridge in articulation. It locks with a notch in the tooth to make for a stronger articulation.

*Derbyia texta*, new species

PLATE 87: FIGURES 1-42

Small, thick walled, biconvex, forming shallow cone, usually undistorted; outline subcircular to semicircular; hinge from slightly to one-third narrower than widest part of shell, slightly articulate in some specimens; commissure even, without consistent sinuosities; most shells regularly plicate, stronger on pedicle valve. Costellae strong, rounded, crenulate, relatively uniform on pedicle valve, but with several markedly stronger primary costellae on brachial valve, intertroughs nearly as wide as costellae; in space of 5 mm costellae numbering between 10 and 17 on pedicle valve, averaging 14, between 11 and 20 on brachial valve, averaging 15; growth laminae strong, more frequent toward margins, relatively evenly concentric on pedicle valve, but scalloped between strong primary costellae on brachial valve.

Pedicle valve with lateral profile normally gently convex or nearly flat, less commonly concave; anterior profile moderately domed; interarea moderately long, flat, or slightly concave or convex, usually strongly apsacline, evenly expanding from apex; pseudodeltidium with proportionately wide arch, but shallow or absent median groove; perideltidium wide, edges near, but not parallel to, edges of interarea.

Brachial valve evenly convex, normally rather

flat, less commonly strongly convex. Median region forming most convex part; anterior part faintly to moderately sulcate.

Pedicle valve interior with strong, compressed teeth; dental ridges converging posteriorly toward apex along edges of delthyrium, meeting at apex, with space between them only rarely filled by callus; median septum low to high, depending on depth of valve, upper edge marking nearly right angle in deep valves, increasingly obtuse angles in progressively shallower valves, septum normally attached directly to underside of pseudodeltidial arch, free of dental ridges, but joined to them by callus in valves with interarea meeting plane of commissure at greatly obtuse angle. Muscle area as long as median septum, occupying from 0.3 to 0.7 valve length, normally nearer 0.3; lightly impressed, with raised borders in some valves, muscle marks normally faint, conspicuous in some, consisting of anteriorly expanding shallow grooves, separated by low longitudinal ridges; sides of median septum bearing faint muscle marks. Floor of valve costellate, with costellae stronger near margins.

Brachial valve interior with strong but short, straight cardinal process, bifurcation at free end shallow, each lobe longitudinally slit, with serrations within slits; dentifers fused to sides of process, forming open hinge sockets, projecting bluntly, and supported by short divergent erismata extending into umbonal arch, continuing as low ridges around posterolateral borders of muscle area. Chelidium well developed, medially scored by continuation of median groove of cardinal process. Muscle area bilobate, bisected by low, indistinct median ridge, muscle marks faint radial or longitudinal striae. Floor of valve faintly costellate, with stronger costellae at margins.

## MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 706b          |                                     |                                      |                          |                        |                             |                  |
| 151177a            | 4.1                                 | ?                                    | 4.9                      | 3.9                    | 2.5                         | ?                |
| 151177b            | 11.1                                | ?                                    | 10.2                     | 9.0                    | 3.9                         | ?                |
| 151177c            | 13.7                                | ?                                    | 10.7                     | 7.7                    | 4.3                         | ?                |
| 151177d            | 15.3                                | ?                                    | 11.7                     | 9.6                    | 6.5                         | ?                |
| 151177e            | 16.1                                | ?                                    | 13.3                     | 10.0                   | 5.0                         | ?                |
| 151177f            | 16.7                                | ?                                    | 15.9                     | 12.6                   | 7.0                         | ?                |
| 151177g            | 14.6                                | ?                                    | 16.5                     | 11.8                   | 6.0                         | ?                |
| USNM 706c          |                                     |                                      |                          |                        |                             |                  |
| 151179a            | 6.8                                 | ?                                    | 5.8                      | 5.5                    | 3.4                         | ?                |
| 151179b            | 8.2                                 | ?                                    | 9.3                      | 8.0                    | 3.6                         | ?                |
| 151179c            | 20.9                                | ?                                    | 19.1                     | 15.0                   | 6.9                         | ?                |
| 151179d            | 18.7                                | ?                                    | 24.0?                    | 19.2                   | 7.3                         | ?                |
| 151179e            | 15.5                                | 13.6                                 | 18.0                     | 12.6                   | 5.0                         | 7.0              |
| USNM 715i          |                                     |                                      |                          |                        |                             |                  |
| 151184             | 24.0                                | 20.8                                 | 25.6                     | 14.2                   | 5.0                         | 10.0             |
| USNM 716x          |                                     |                                      |                          |                        |                             |                  |
| 152618             | 17.8                                | 14.6                                 | 16.8                     | 13.5                   | 4.6                         | 8.8?             |
| USNM 707e          |                                     |                                      |                          |                        |                             |                  |
| 152616a            | 25.6                                | ?                                    | 24.5                     | 18.4                   | 8.2                         | 10.0?            |
| 152616b            | 24.6                                | ?                                    | 21.0                     | 16.3                   | 4.4                         | 4.6              |
| 152616c            | 14.1                                | 12.7                                 | 17.9                     | 11.8                   | 3.0                         | 7.0              |
| 152616d            | 12.1                                | 10.2                                 | 13.0                     | 9.6                    | 2.6                         | 3.7              |
| 152616e            | 11.2                                | 8.7                                  | 11.7                     | 9.3                    | 3.3                         | 3.7              |
| 152616f            | ?                                   | 15.5                                 | 20.6                     | 18.3                   | ?                           | 3.8              |
| 152616g            | ?                                   | 18.0                                 | 20.6                     | 14.1                   | ?                           | 7.7              |
| 152616h            | ?                                   | 15.8                                 | 18.4                     | 15.6                   | ?                           | 4.3              |
| USNM 706e          |                                     |                                      |                          |                        |                             |                  |
| 153449b (holotype) | 16.5                                | 14.0                                 | 20.0                     | 13.0                   | 6.8                         | 9.6              |

STRATIGRAPHIC OCCURRENCE. — Cherry Canyon Formation (Getaway Member), Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members and lenses between the last two), Bell Canyon Formation (Hegler, Rader, and Lamar members).

LOCALITIES.—Getaway: Moore 31, AMNH 505, 506, 512, 519, 600, USNM 728, 732, 736; Road Canyon: USNM 703, 703c, 703d, 707e, 716x, 724a, 726o; China Tank: USNM 706c, 713, 726r; Willis Ranch: USNM 706, 706e, 724u; lens: USNM 706b, 732c, 742b; Appel Ranch: USNM 704, 706d, 714o, 715i, 719z, 727j; Hegler: USNM 731; Rader: AMNH 403, USNM 725f, 725g; Lamar: USNM 725e, 738b.

DIAGNOSIS.—Small *Derbyia* with strong costellae and poorly formed radial plications.

TYPES.—Holotype: USNM 153449b; figured paratypes: 151179e, 151176, 151184, 151186, 153449c, e,

f; measured paratypes: 151177a–g, 151184, 152616a–h, 152618; unfigured paratypes: 153449d.

*Derbyia filosa* has the same average number of costellae per 5 mm as *D. texta* and occurs in many of the same samples. Those two species are not closely similar, however. *Derbyia filosa* attains a maximum size about three times as large as the largest *D. texta* and does not have the webbed ornament, plicate brachial valve, and, most distinctively it has the dental ridges and median septum fused so that a small recess for the cardinal process is produced beneath the pseudodeltidial arch (not a true camera).

DISCUSSION.—*Derbyia texta* varies in the convexity of its valves, width of hinge, and angle between the plane of commissure and the interarea. Its other features are rather consistent and vary only within narrow limits. Of course size changes with growth,

and the number of costellae per unit distance ranges about a mean. Counts of costellae in 5 mm on specimens from two localities illustrate this variation:

|                          |                                    |  |  |  |  |  |  |  |
|--------------------------|------------------------------------|--|--|--|--|--|--|--|
|                          | <i>pedicle valves</i> (USNM 706b)  |  |  |  |  |  |  |  |
| number of costellae/5 mm |                                    |  |  |  |  |  |  |  |
| number of specimens      |                                    |  |  |  |  |  |  |  |
|                          | <i>brachial valves</i> (USNM 706b) |  |  |  |  |  |  |  |
| number of costellae/5 mm |                                    |  |  |  |  |  |  |  |
| number of specimens      |                                    |  |  |  |  |  |  |  |
|                          | <i>pedicle valves</i> (USNM 706c)  |  |  |  |  |  |  |  |
| number of costellae/5 mm |                                    |  |  |  |  |  |  |  |
| number of specimens      |                                    |  |  |  |  |  |  |  |
|                          | <i>brachial valves</i> (USNM 706c) |  |  |  |  |  |  |  |
| number of costellae/5 mm |                                    |  |  |  |  |  |  |  |
| number of specimens      |                                    |  |  |  |  |  |  |  |

Derbyia species

Many specimens of *Derbyia* collected by us and members of parties from the American Museum of Natural History cannot be identified with the species described herein or elsewhere. This is owing to poor material or to specimens that are too few or too variable to resolve into understandable species. Although such specimens occur in nearly all of the formations collected, the largest number occur in the members of the Bell Canyon Formation. At least three species occur in these beds, but all of the specimens are dissociated valves, many of them with ragged edges and many of them immature. Remarks on these are given below.

Derbyia species 1

PLATE 88: FIGURES 7-31

?*Derbyia* species *a* Girty 1909:184, pl. 11: fig. 1 [probably not pl. 10: fig. 11].

Moderately large for genus, outline subrectangular, width slightly greater than length. Sides rounded; anterior margin broadly rounded, slightly linguoidal; hinge wide but not equalling maximum width at about midvalve. Cardinal extremities varying from obtuse to narrowly auriculate. Costellae fine, variable in size, intercalated in 3 generations, crenulated and more numerous on brachial valve, more distant on pedicle valve. Costellae numbering (brachial valve) 13 in 5 mm at 10 mm anterior to beak; (pedicle valve) numbering 9 in 5 mm at

10 mm anterior to beak and same number at margin.

Pedicle valve flatly convex in lateral profile, gently convex in anterior profile; interarea short, apsacline. Teeth small; median septum short, delicate, reaching about one-third valve length.

Brachial valve moderately convex in lateral profile with maximum curvature in umbonal region; anterior region profile broadly convex; sulcus moderately broad, shallow, originating just anterior to umbonal curvature, persistent at all states of growth represented in collection. Median region moderately swollen. Chilidium small, strongly bilobed; cardinal process short; supporting plates flaring but short.

MEASUREMENTS (in mm).—Pedicle valve (151205a): length 35.0 (estimated), maximum width 41.6, hinge width 34.0, interarea length 5.9, thickness 5.0 (estimated); brachial valve (151205b): length 34.2, maximum width 43.7, hinge width 32.8, thickness 9.0.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Lamar Member).

LOCALITIES.—AMNH L-2, 37, 38, 40, 347, 373, 385, 398, 430L, 430M, USNM 725e, 728p, 738, 738b.

TYPES.—Figured specimens: USNM 151205b, c, 153465a, b, 153466a, b, 153467a-c.

DISCUSSION.—We refer here the large specimen figured by Girty as “*Derbyia* species *a*,” which has essentially the same form and profile of brachial valves of the silicified specimens from the Lamar Limestone. This has a length of 57 mm and an estimated width (based on half measure) of 77 mm.

If the suggested relationship ultimately proves correct, this species will be one of the larger derbyias of the Permian. A few specimens of larger posterior parts preserving the cardinal process indicate a huge *Derbyia* in the Capitan and its equivalents.

### *Derbyia* species 2

This species is represented by a brachial and a pedicle valve. The brachial valve is unlike any other found in the West Texas Permian. It is strongly alate and mucronate, the hinge being very wide and drawn into long points. The median region is marked by a deep sulcus that extends from the umbo to the anterior margin, where it is deep and causes an indentation in the anterior margin. The ornament consists of the usual fine costellae, but these are superimposed over numerous narrow plications that originate on the anterior slope about 10 mm anterior to the beak. About 10 plications appear on each side.

The pedicle valve is less well preserved than the brachial and is not complete. It is moderately swollen medially. The interarea is short and curved and apparently apsacline. The median septum is partly covered but appears to have been very long.

The specimens come from the Road Canyon Formation at USNM 703d.

Types.—Described specimens: USNM 152615a, b.

### *Derbyia* species 3

A large brachial valve 61.5 mm long by 95 mm wide near midvalve represents a species of gigantic proportions of which good material is yet to be found.

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation.

LOCALITY.—USNM 715.

Types.—Mentioned specimen: USNM 155029.

### *Nothopindax*, new genus

[Greek *nothos* (false) + *pyndax* (bottom of a vessel)]

Large, wider than long, biconvex, the pedicle valve often subconical; hinge not equal to widest part, which is at about midvalve; interarea long; pseudodeltidium narrow, flattened distally and with prominent monticulus; anterior commissure not

conspicuously folded; surface costellate, costellae fine, crowded.

Pedicle valve interior with strong teeth and dental ridges; apex with small triangular chamber formed of false dental plates uniting with median ridge that, in turn, supports spatula-like muscle platform from ventral side.

Brachial valve interior with no chilidium but long, slightly curved bifurcated cardinal process with obscure dentifer, with long widely divergent supporting plates (erismata).

TYPE-SPECIES.—*Nothopindax egregius*, new species.

DIAGNOSIS.—Derbyiinae having a distally free muscle platform and small apical chamber.

COMPARISON.—The brachial valve interior of this genus indicates relationship to *Derbyia* as shown by the reduced dentifer and widely divergent supporting plates. The myophore and shaft are actually longer than usually seen in *Derbyia* and are more like *Meekella* in this respect. In spite of its length the cardinal process is more derbyoid for the reasons first stated. The distinctive generic characters are seen, however, in the pedicle valve.

The combination of characters in the pedicle valve are unlike any other known genus. The presence of a median septum and apical chamber suggest *Orthotetes*, but the median septum is not attached to the valve floor. The triangular chamber is based posteriorly on the posterior edge or side of the proximal part of the median septum, but the septum is the support for a muscle platform having the shape of a spatula, widening distally, and attached to the anterior edge of the median septum. This combination is unique among Derbyiacea.

DISCUSSION.—All elements of the pedicle apical apparatus are variable. Actually no two specimens are really alike except in gross form. The triangular apical chamber ranges from shallow and small to elongate and tubular, and in one specimen the chamber is completely closed by callus deposition. The sides of the chamber in some specimens join the posterior edge of the septum, but in the largest specimen the sides of the chamber attach to the sides of the septum. The spatuloid muscle platform varies from narrowly spatulate to distally widely spatulate. In some specimens this plate narrows so strongly apically that it scarcely overlaps the sides of the septum at the apex. In another specimen



the plate maintains considerable width toward the apex and widely overlaps the septum.

The muscle platform is also buttressed from beneath in some specimens. In one it is bolstered by a fold of the shell rising to its base and uniting with it. In the other valves an oblique or nearly vertical plate is built up on one side of the muscle platform. This plate is not placed medially as one might expect, but it is generally off center. A single specimen shows the plate buttressed by a pair of supporting plates symmetrically placed. In several specimens, including the type, the muscle platform is supported only by the median septum.

### *Nothopindax egregius*, new species

PLATE 96: FIGURES 1-14; PLATE 97: FIGURES 1-10;  
PLATE 98: FIGURES 1-15

Very large, biconvex, broad to deeply conical, relatively symmetrical to greatly distorted; shell wall greatly but erratically undulating to very bumpy and concentrically or irregularly ridged; outline uneven, transversely subelliptical to nearly semicircular; hinge between 0.65 and 0.85 total shell width, auriculate on one or both sides in some specimens; commissure irregular in detail, but without consistent folding. Costellae low, rounded, added anteriorly by insertion, not closely crowded, numbering between 12 and 22 on brachial; growth lines moderately strong, becoming laminae near margins.

Pedicle valve flatly to strongly convex to deeply conical; lateral profile convex to concave, commonly abruptly flexed at one or several places; interarea wide, moderately long, flat, concave or convex, often twisted, meeting plane of commissure near right angle, at large acute angle (projecting forward) or small obtuse angle (apsacline to catacline to procline); perideltidium occupying at least half of width of interarea; pseudodeltidium narrow, evenly expanding anteriorly, with monticulus, strongly arched, nearly constant in width, 2 lower and gentler lateral ridges at edges of

pseudodeltidium, marking traces of forward growth of hinge teeth. Brachial valve strongly convex, normally not as irregular as pedicle valve, maximum convexity near beak; umbonal and median regions swollen; lateral slopes steep.

Pedicle valve interior with strong teeth projecting forward from underside of interarea, extending posteriorly along edges of pseudodeltidium as converging dental ridges, meeting at or near apex of valve; dental plates along posterior half of ridges strong, converging and fusing to top of median septum, thus producing long, narrow, shallow chambers like that of *Orthotetes*. Median septum long but low, posterior half of its upper edge braced by dental plates, lower edge laterally widened and flattened into a broad muscle platform; base of muscle platform fused to valve floor near apex, rising anteriorly free of floor except for median or lateral bracing by adventitious plates, whose location depends upon local undulations of valve floor; sides of platform gently diverging from apex of valve, suddenly widening at some distance anterior to apex, then again widening gently, converging, or remaining subparallel to end of septum, there converging to form gently rounded to slightly nasute distal end of platform. Muscle marks on sides of median septum and on top and bottom of muscle platform. Floor of valve bumpy, faintly costellate, costellae stronger near edges.

Brachial valve interior with long, strong, curved cardinal process, bifid at free end, prongs divergent, each longitudinally slit along posterior edge, with serrations for muscle attachment within slits, prongs fusing posteriorly, the junction forming low median crest of process; dentifers small, an extension projecting slightly and bluntly into body chamber; erismata continuous with dentifers, high, strong, divergent into umbonal cavity, outlining posterolateral boundaries of muscle area. Chilidium absent. Anterior edges of muscle area obscure on all known specimens, probably similar to that of *Derbyia pannucia*, new species. Valve floor irregular, finely costellate, costellae stronger at margins.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701h          |                            |                             |                  |                |                     |           |
| 151225a            | 10.5                       | 9.6                         | 11.4             | 10.5           | 8.8                 | 13.0      |
| 151225b            | ?                          | ?                           | 55.5             | 44.5           | 26.0                | 26.8      |
| 151225c (holotype) | 31.8                       | 31.8                        | 35.0             | 28.8           | 24.5                | 30.8      |
| 151225d            | 43.9                       | ?                           | 63.0?            | 36.0?          | 20.0                | ?         |
| 151225e            | 80.3                       | ?                           | 125.0?           | 112.9          | 46.4                | ?         |
| 151226a            | 71.5                       | 71.5                        | 90.7             | 51.8           | 20.4                | 60.5      |
| 151226b            | 78.0                       | 78.0                        | 96.4             | 46.5           | 29.0                | 67.6      |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 9–12 of Cooper=bed 12–14 of P. B. King).

LOCALITIES.—USNM 701a, 701h, 701k.

DIAGNOSIS.—Large *Nothopindax* with rough and irregular surface.

TYPES.—Holotype: USNM 151225c; figured paratypes: 151225a, b, d–f, 151226a, c, d, e, 151227a, b, 153468; unfigured paratypes: 151226b, d.

COMPARISON.—*Nothopindax egregius* is characterized by its bumpy and irregular shell that is moderately to strongly biconvex or deeply conical, its wide and moderately long interarea with narrow, triple-arched pseudodeltidium, absence of chilidium, strong and crested cardinal process, high supporting plates, and especially by its raised muscle platform and the pair of short dental plates that brace the upper edge of the median septum and form a long but shallow camera. The platform and narrow triple-arched pseudodeltidium distinguish the species from all species of *Derbyia*; the narrow median arch of the pseudodeltidium and the dental plates and camera distinguish it from most species of *Derbyia*.

This species differs from *Orthotetella* King in its narrow median pseudodeltidial arch, raised platform, and narrower spondylium formed by plates that are extensions of the dental ridges rather than by independent plates.

DISCUSSION.—The collection of *N. egregius* is small, but the specimens are well preserved. The species is rather broadly conceived and, with larger collections, may be found to include more than one species. All specimens are from three localities in beds 9 to 12 (of Cooper) of the Neal Ranch Formation in the Wolfcamp Hills. Of the three different varieties that might be distinguished, all occur

at USNM 701h. The following characterization of these varieties is intended to indicate the amount and nature of known variation and to point out what later may be considered new species. As it is, the collection is treated as a small sample from the population of one variable species.

*Variety A.* This variety contains the holotype of *N. egregius*. It attains large size, has the muscle platform gradually expanding toward its free end, and is suddenly widened and spatulate near that end. The support of the base of the muscle platform is short, single, and median, or nearly so. The shell is gently convex to conical.

*Variety B.* These shells are shallow to deeply conical, relatively unwrinkled, have expansion of the spatulate muscle platform very near the apex, normally near the place where the platform rises free of the valve floor. Support beneath the platform normally is double, consisting of two short, longitudinal lateral plates. The platform in some is supported by one lateral plate, and an adventitious bump in the valve floor that rises to meet the other side of the platform. In this variety the entire septal apparatus is proportionately shorter and broader than in varieties A or C.

*Variety C.* This variety is represented by a single pedicle valve in which the septa are proportionately long, the muscle platform expands to its widest near the apex of the valve and gradually narrows toward the free end of the septum, and the platform is supported by a plate on one side and by a fortuitous intersection with a bump in the floor on the other side near the free end. This specimen may be an atypical example of variety B, one in which the septal apparatus is exceptionally elongate.

### Subfamily OMBONIINAE Sokolskaya, 1960

Costellate, nonplicate Derbyiacea having dental plates that make narrow, long spondylium in pedicle valve, and short myophore but long supporting plates (erismata) in brachial valve.

This subfamily at present has only the single genus *Ombonia*. The cardinal process with its small myophore but enormous erismata seems to us to be an aberration of the Derbyiidae. Sokolskaya (1960: 218) assigns *Geyerella* and *Orthotetes* to the subfamily evidently on the presence of spondylia, but the spondylia and cardinal process are so different in each genus as to deny the two genera admission to the same subfamily. Several other genera related to *Orthotetes* or having a cardinal process like that of *Meekella* also have been placed here, but we reassign *Perigeyerella* and *Sicelia* to the Meekellidae, because of their elongated cardinal process, and *Werriea* and *Permorthotetes* to the Derbyoidinae, because of the short schuchertelloid cardinal process with cuplike sockets. *Orthotetella* R. E. King, in spite of its anomalous cardinal process, is closer to *Derbyia* than to *Ombonia*. The idea that *Ombonia* is related, even remotely to *Orthotetes*, is entirely counter to our views because of the differences in cardinalia and spondylia.

### Genus *Ombonia* Caneva, 1906

*Ombonia* Caneva, 1906:54; 1907:438, pl. 9: figs. 6–12.—Merla, 1930:79.

Shell small to moderately large, shallow to deeply conical; often distorted; outline transversely subelliptical to nearly circular; hinge narrower than midwidth; anterior commissure rectimarginate to uniplicate; costellae fine, delicate, increasing anteriorly by insertion, slightly more densely crowded on brachial valve; intertroughs narrow, sharp; growth lines faint to strong, normally only slightly more closely spaced near margins.

Pedicle valve semiconical, evenly expanding to attenuate, apex sharp or blunt; lateral profile normally convex, flat, or concave in some specimens; interarea relatively wide, short, or long, slightly concave to slightly convex, meeting plane of commissure near right angle or strongly apsacline; perideltidium narrow or wide, obscurely delimited; pseudodeltidium completely arched. Brachial valve flatly to strongly convex, convexity even or strongest near beak, which overhangs interarea.

Pedicle valve interior with long hinge teeth at edges of pseudodeltidium, converging apically beneath interarea as dental ridges, meeting at apex, extending toward floor of valve as thin ventrally convergent dental plates, meeting above floor to join the median septum, which extends about to mid-valve; muscle marks faint.

Brachial valve interior with short to moderately long, straight or slightly curved cardinal process, bifid for short distance at free end, each branch longitudinally slit, with serrations within slits, branches joining to form low median crest of process, attached end may be partly covered by small, distinct, medially grooved chilidium, or chilidium may be absent. Dentifers well developed; fused to sides of process, curving along length of process and projecting slightly ventrally below it, forming shallow hinge sockets; erismata continuous with dentifers, narrowly and straightly diverging into umbonal cavity, outlining posterolateral margins of muscle area. Muscle marks faint, within lobate muscle area, may be subdivided by low median ridge.

TYPE-SPECIES.—*Ombonia canevei* Merla (1930:80, pl. 7: figs. 13–21).

DIAGNOSIS.—Derbyiacea with fine costellae and without plications, having a long narrow spondylium in the pedicle valve and a short cardinal process with unusually long divergent erismata in the brachial valve.

COMPARISON.—*Ombonia* is a very distinctive genus with its fine even costellae, lenticular profile, generally wide hinge, and elongated interarea. Texas specimens seem not to be so readily distorted as some of the related genera although the living habits of *Ombonia* undoubtedly were the same as those of most Derbyiacea. Two features of the interior are distinctive: one of them is the spondylium, which suggests relationship to *Orthotetes*, and the other is the cardinal process, which is suggestive of *Derbyia*. A number of authors have considered *Ombonia* and *Orthotetes* to be the same because each has a spondylium and have recommended discarding *Ombonia*, which is the younger name. The type of spondylium of *Ombonia* is so different from that of *Orthotetes* that confusion seems unlikely. If it should not be conceded that the spondylia of the two genera are unlike, the difference in the cardinalia should dispel any doubts.

In *Orthotetes* the cardinalia are not provided with supporting plates of any sort, whereas in *Ombonia* the cardinalia are buttressed by widely divergent and extremely long erismata that reach midvalve in some specimens.

DISCUSSION.—It is important to discuss the shell anatomy of *Ombonia* in some detail because of the confusion between it and *Orthotetes*. Silicified specimens of *Ombonia* from the Guadalupe Mountains and Glass Mountains show the details of anatomy to perfection and should eliminate all doubt as to the distinctness of the two genera.

The type-species of the genus and the specimens from Texas are distinctive externally as well as internally. The costellae are generally low, fine, numerous intercalated, but large and small ones are not usually strongly differentiated and are not set into zones of fine ones bounded by thick ones. The shell itself is generally well proportioned and not usually greatly distorted, having a broadly elliptical outline and conical profile. It is probable that *Ombonia* lived the early part of its life attached, and thus some specimens were subject to distortion. The interarea of the attached shells is considerably elongated and twisted in some fashion. Such specimens are not common in the Texas material.

The interarea is usually long, generally flat, but some specimens have this feature concave or slightly convex. The perideltidium is usually well developed and strongly marked by vertical striae. The pseudodeltidium commonly is strongly arched and usually has a depressed median line that corresponds to the gap in the chilidium, exactly opposite to the monticulus of *Meekella*. This gap produces a sag in the anterior edge of the pseudodeltidium at a point where it makes contact with the chilidium. This is a feature common in *Derbyia*.

Inside the pedicle valve the spondylium is very distinctive. It is narrowly like that of *Geyerella* and its general construction is similar. The dental plates buttress the sharp and long teeth as dental ridges, which expand posteriorly to form thin and delicate dental plates. These converge rapidly to form a V, which is attached to a low, delicate median septum, producing a Y-shaped cross section. Anteriorly this slopes rapidly to the valve floor and is not continued anteriorly. *Ombonia invecta*, new species, has a spondylium that does not reach to midvalve, but

that of *O. guadalupensis* (Girty) reaches about to midvalve in adults.

The spondylium is variable in the height of the median septum, in the width of the V-shaped chamber and the amount of recession of the dental plates. The anterior edges of the dental plates are generally concave toward the apex, strongly in *O. guadalupensis*, but less so in the Glass Mountain species. In the species from the Getaway Member the median septum is very low and some of the spondylia seem almost to rest on the valve floor.

A sufficiently large number of juveniles has not yet been found to determine definitely at what stage the dental plates form the spondylium. One specimen of *O. invecta*, only 3 mm long, appears to have a sessile spondylium, but a juvenile of *O. guadalupensis*, 5 mm long, has a well-formed spondylium. We have not found muscle scars around the base of the spondylium on the valve floor, and muscle marks in the spondylium are obscure. To what muscles these should be assigned is a matter of conjecture.

Inside the brachial valve the cardinal process and associated structures are as characteristic of *Ombonia* as is the spondylium. The chilidium is a prominent bilobed structure forming two narrowly convex lateral lobes with a deep groove between. These lie over the posterodorsal or proximal extremities of the myophore and are firmly strengthened by a lateral extension that covers the interarea and is anchored on the sloping outer face of the myophore. Like the Derbyiidae the myophore is forked, the two prongs divergent, but usually not widely so. The cleft between the lobes is usually short. Each lobe is slit and the sides of the slit are crenulated as usual. The surprising fact about the myophore is its brevity, because it does not protrude into the valve as far as the ends of the dentifers, yet *Ombonia* is a relatively deep shell.

Anterior to the myophore for a short distance occurs a narrow ridge or fold on the long sloping outer face of the cardinal process, which is the upper surface of the dentifer and which, at the same time, helps to define the socket. This ridge is compared to the promontorium of the elaborate cardinal process of *Meekella*. In *Ombonia* this ridge is never so greatly developed as in *Meekella*. Anterior to the dentifer is another ridge, which in this genus is unusually protuberant. Furthermore, an



anterior line can be discerned running across the sloping face of the cardinal process. This line and the dentifer are equivalent to the brachiophore and make a broad, flat blade. Anterior to the lower defining line of the brachiophore is the long sloping face of the supporting plate. The erismata are slender but strong and are divergent in different degrees, depending on the species, but are constant within limits. These buttress plates define the large adductor field, but individual scars have not yet been identified in the genus. A rudimentary myophragm appears at the middle of this region in some specimens, but it is not a constant or important feature.

A final feature of the brachial valve is seen along the hinge, a narrow interarea that usually does protrude when the valves are articulated. It is not concave and thus is probably not a ginglymus. Anterior to the interarea on the inside of some specimens is a narrow parallel groove bounded by a low ridge. In old shells this becomes a broad, flat thickening that helps to strengthen the hinge region.

In the Guadalupe Mountains *Ombonia* is commonest in the debris from reefs and in calcarenites. The shells in the Capitan Formation are usually single valves, but a small percentage of specimens can be recovered with both valves in contact. In the acid residues of the Capitan equivalents, Lamar and Rader limestones, the genus has not yet been taken with both valves in contact. These members are thought by some geologists to represent slide from the reefs. Consequently, considerable breakage and separation of valves is to be expected. No direct evidence on the life habits of *Ombonia* has been seen, but no reason is apparent that they lived in a manner unlike that of the other Derbyiidae. Slightly distorted beaks, thinned beak regions, and noncostellate patches on the umbonal region of the pedical valve all point to attachment. Probably early attachment and later freedom, as in many species of *Derbyia*, was the usual habit.

Greco (1942:146), Licharew, and other authors regarded *Ombonia* and *Orthotetes* as synonyms. Their arguments were based on the fact that the two genera share in common a spondylium that is an unusual structure in these brachiopods. These authors did not consider the unlike character of the spondylia of the two genera as important, nor did

they consider the great differences in the cardinal processes. The latter structure long has been overlooked in the taxonomy of these difficult shells, but it has been brought into notice by G. A. Thomas (1958:12), who suggests its great importance in the Orthotetacea as well as in other major groups, where it has been more successfully used.

The rich fauna of the Sosio Limestone in Palermo Province, Sicily, includes many types of Orthotetacea, including some forms referred to *Ombonia*. These are robust species, usually with somewhat distorted beaks and showing evidence of attachment in a reefy environment. These long beaked forms have a greatly elongated cardinal process entirely different in type from that of *Ombonia*, and only a modest development of the supporting plates is indicated. It is probable that these forms represent a different development of *Ombonia* from an entirely different stock and are probably an aberration of *Sicelia*. They conform well to Wang's (1955:346) genus *Perigeyerella*.

*Ombonia* occurs in the Cherry Canyon and Bell Canyon formations. In the former it has been taken from the Getaway Member, but it appears to be very rare and the few specimens in the national collection are not sufficient for the establishment of a species, although clear differences from *O. guadalupensis* (Girty) and *O. invecta*, new species, are indicated. *Ombonia* is abundant in many parts of the Capitan limestone and is rare in the Rader but common in the Lamar Member of the Bell Canyon Formation.

In the Glass Mountains, *Ombonia* is one of the rarest of prizes, having been found only in a Road Canyon lens taken at the base of the Word Formation about 25 feet above the main part of the Road Canyon Formation in Gilliland Canyon and in one place in the Sierra del Norte. In the Road Canyon it occurs with *Geyerella*, an association that made separation of the two genera very difficult. At USNM 720d it is heavily coated with a possible algal smear. Other associates of *Ombonia* in this lens suggest relationship with the Road Canyon fauna rather than with the Word above.

### *Ombonia guadalupensis* (Girty)

PLATE 90: FIGURES 1-33; PLATE 91: FIGURES 1-16;

PLATE 92: FIGURES 26-38

*Orthotetes guadalupensis* Girty, 1909:199, pl. 10: figs. 1-5.  
*Orthotetes declivis* Girty, 1909:200, pl. 10: figs. 6-8a.



Shell usually small, shallow to deeply conical, symmetrical to slightly distorted; outline transversely subelliptical to subquadrate; hinge slightly narrower than midwidth; sides rounded; commissure normally broadly uniplicate. Costellae low, fine, numbering between 15 and 25 in 5 mm, averaging about 21 on pedicle valve and about 22 on brachial; intertroughs narrow; growth lines faint, visible only near margins.

Pedicle valve evenly expanding to attenuated, beak usually sharp, more rarely blunt; lateral profile normally gently convex, often flexed; anterior profile broadly to flatly convex; interarea moderately wide, short to long, slightly concave to slightly convex, usually flat, apsacline; perideltidium obscure, less than half width of interarea at hinge; pseudodeltidium completely arched, with shallow median groove anterior with short tongue in folded specimens.

Brachial valve flatly to strongly but evenly convex, without prominent or overhanging beak; median region swollen; young adults flattened anteromedially, but old shells with obscure fold.

Pedicle valve interior with long pointed teeth projecting forward from underside of interarea,

extending posteriorly as sharp convergent dental ridges, meeting at apex of valve, and extending anteriorly as convergent dental plates, meeting the median septum to produce a long, narrow triangular spondylium reaching to nearly midvalve; anterior edges of dental plates curved forming apically curved arc; muscle marks faint striae within spondylium. Floor of valve weakly costellate, costellae stronger marginally.

Brachial valve interior with short, slightly curved cardinal process having a shallow bifurcation at free end, each branch longitudinally slit, with minute serrations within slits; branches of process joining to form low crest with median groove along most of length; attached end embossed with small but distinct bilobed chilidium; dentifers fused to sides of process, projecting in nearly same direction as branches of process, only slightly more anteriorly; erismata long, narrowly and straightly diverging into umbonal arch of valve, bordering posterior of muscle area. Muscle marks faint, within anteriorly curved, weakly impressed muscle area, bisected by a low median ridge in some specimens. Valve floor weakly costellate, costellae stronger near margins.

#### MEASUREMENTS (in mm).—

|                     | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|---------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USGS 2926           |                                     |                                      |                          |                        |                             |                  |
| 118502a (lectotype) | 15.8                                | 14.2                                 | 19.6                     | 12.6                   | 7.3                         | 11.3             |
| 118502b             | 16.4                                | 15.0                                 | 18.6                     | 12.6                   | 9.3                         | 13.3             |
| USNM 737a           |                                     |                                      |                          |                        |                             |                  |
| 147757a             | 27.2                                | 22.5                                 | 33.0                     | 20.1                   | 8.8?                        | 16.3             |
| USNM 750            |                                     |                                      |                          |                        |                             |                  |
| 147763a             | 17.6                                | 15.5                                 | 20.2                     | 15.2                   | 9.4                         | 17.0             |
| 147763b             | 12.9                                | 11.0                                 | 14.3                     | 10.7                   | 12.0?                       | 15.7?            |
| AMNH 430            |                                     |                                      |                          |                        |                             |                  |
| 151005              | 23.9                                | ?                                    | 30.0                     | 22.8                   | 9.8                         | 9.6              |
| AMNH 389            |                                     |                                      |                          |                        |                             |                  |
| 152607              | ?                                   | 24.1                                 | 32.1                     | 25.1                   | ?                           | 9.8              |

STRATIGRAPHIC OCCURRENCE.—Capitan Formation, Bell Canyon Formation (Lamar Member).

LOCALITIES.—Capitan: AMNH 725, USGS 2926, USNM 725g, 725p, 737a, 750; Lamar: AMNH L-2, L-3, L-6, 25, 37, 38, 39, 40, 347, 348, 389, 430, USNM 725e, 728i, 728p, 728q, 738, 738b.

DIAGNOSIS.—Moderately large *Ombonia* with

very fine costellae, generally symmetrical shells and long narrow spondylium.

TYPES.—Holotype: USNM 118502a; unfigured paratype: 118502b; figured hypotypes: 150996a, f, 150997a, -1 151000a, 151003a, b, 151005, 152607, 153478a-i, 153552a, b; measured hypotypes: 147757a, 147763a, b, 150996b-e, 151005, 152607.

*Ombonia guadalupensis* differs from "*Ombonia*"

*magna* Greco (1942:147) from the Sosio Limestone of Sicily in its smaller and less distorted shell, shallower and sharper pedicle valve, much weaker growth lines, and completely arched pseudodeltidium that accommodates a chilidium. The Sicilian species is more coarsely ornamented, deeper, and lacks a chilidium because of the very narrow median arch of its pseudodeltidium. As noted above, these two may be generically distinct.

***Ombonia invecta*, new species**

PLATE 35: FIGURES 1-17; PLATE 62: FIGURES 3, 4

Usual size for genus, broadly elliptical in outline, elongate conical in profile; hinge narrower than maximum width, which is at midvalve; sides rounded; anterior margin broadly rounded to slightly flattened; anterior commissure rectimarginate. Surface costellate, costellae low, flatly rounded, and closely crowded, appearing by intercalation in several generations, about 20 in 5 mm at 10 mm anterior to beak and 18 at anterior margin of adult brachial valves.

Pedicle valve triangular in lateral profile, inter-

area and ventral side forming acute angle with long side of angle faintly concave or flat; anterior profile broadly and gently rounded; interarea long, varying from slightly concave to slightly convex, procline to apsacline; perideltidial area prominent, width greater than half width between pseudodeltidium and valve edge; pseudodeltidium with slight median groove, narrow, and strongly convex. Umbonal region flattened; median region usually flattened to concave. Lateral slopes rounded.

Brachial valve evenly and moderately convex in lateral profile, broadly domed in anterior profile, sides moderately steep; median region strongly swollen with moderately steep umbonal and lateral slopes; anterior slope moderately steep.

Pedicle valve interior with receding dental plates forming short narrow spondylium with short median septum not reaching midvalve.

Brachial valve interior with small bilobed chilidium; myophore lobes short, slightly convex anteriorly, with short cleft; dentifers broad and flat, bounding small socket; erismata diverging at about 60° and extending about one-third valve length. Muscle marks not impressed.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720d          |                            |                             |                  |                |                     |           |
| 150995a (holotype) | 15.8                       | ?                           | 19.4             | 14.0           | 13.3                | 13.3      |
| 150995b            | 12.8                       | ?                           | 17.2             | 10.9           | 9.0                 | 8.7       |
| 150995c            | 11.0                       | ?                           | 14.6             | 11.5           | 8.2                 | 8.5       |
| 150995d            | 12.5                       | ?                           | 13.9             | 8.8            | 6.5                 | 5.8       |
| 150995e            | ?                          | 15.2                        | 22.4             | 19.0           | ?                   | 6.5       |
| 150995f            | ?                          | 14.4                        | 18.6             | 15.5           | ?                   | 3.9       |
| 150995g            | ?                          | 11.0                        | 14.1             | 9.8            | ?                   | 3.8       |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation (lens 25 feet above Road Canyon limestones and ammonite bed).

LOCALITY.—USNM 720d, 737n.

DIAGNOSIS.—Broadly elliptical *Ombonia* with predominantly long interarea and short narrow spondylium.

TYPES.—Holotype: USNM 150995a; figured paratypes: 150995d, e, i-m; measured paratypes: 150995b-g; unfigured paratypes: 150995b, c, f-h.

COMPARISON.—This species attains approximately the same size as *O. guadalupensis*, but it differs in having generally a longer interarea, yet, at the

same time, a shorter spondylium, the median septum of which does not reach midvalve. The costellae appear to be slightly stronger than those of specimens from the Guadalupe region, but they are partly obscured on the specimens available and the counts are not entirely satisfactory.

DISCUSSION.—Like all of the other interesting species occurring in the blocks at this locality, the shells are covered by a siliceous crust. This has a sort of pattern that leads to the belief that the crust may have been an algal deposit of some sort. The crust covers either or both sides, obscuring many details. Fortunately, sufficient specimens were

recovered to exhibit most of the details of the species, but making satisfactory photographs of them was difficult.

The significant feature of this species is the brevity of its spondylium. This is a delicate structure, very narrow, and attached to a short median septum, which is short both dorsoventrally and in the valve length. In the young the spondylium has a very low septum, and it is possible that early juveniles have the spondylium sessile. The anterior edge of the spondylium is generally straight, rather than concave posteriorly, as in *O. guadalupensis*.

The pseudodeltidium is definitely grooved medially, which is a response to the bilobed chilidium and is a feature characteristic of *Derbyia* and its allies. The brachial valve presents no unusual features, but the brachiophore is generally very well marked and strongly protuberant.

This species is rare in the Glass Mountains, where it is associated with species characteristic of the Road Canyon Formation, although the lens from which the specimens were taken occurs about 25 feet above the top of that formation.

### *Ombonia* species 1

PLATE 90: FIGURES 34-41

A third species of *Ombonia* is indicated by fragmentary specimens from the lower Getaway Member of the Cherry Canyon Formation at USNM 732. Of the 16 valves (11 of them brachial valves) available for study, not one is complete enough to get more than a general idea of the species. It is roundly elliptical in outline with a strongly conical pedicle valve, having a long interarea, and with a wide perideltidial region and a broad, sulcate pseudodeltidium. The teeth are short inside the pedicle valve, but the spondylium is fairly wide (5 mm in a specimen 32 mm wide) with sides moderately concave posteriorly. The median septum is very low and short, not extending anterior to the spondylium.

The brachial valves do not present any structural peculiarities, but their features are well marked because the shells are fairly thick. The dentifer in one specimen is unusually long. On the exterior the costellae appear coarser than the other two species, and on one brachial valve stronger costellae are intercalated among the finer ones.

MEASUREMENTS (in mm).—USNM 147758a (pedicle valve): length 22.0, maximum width 32.0\*, hinge width 22.0, interarea length 11.0, thickness 9.0; USNM 147758b (brachial valve): length 14.6, maximum width 21.8, hinge width 20.0\*?, thickness 4.7.

TYPES.—Figured specimens: USNM 147758a-c.

### Family STREPTORHYNCHIDAE Stehli, 1954

Derbyiacea without dental plates or septum in pedicle valve but with cardinal process having erismata. Exterior costellate, costate or both.

Most species formerly referred to *Streptorhynchus* are now placed in different categories. Genera recognized in the Glass Mountains are: *Chelononia*, new genus; *Bothrostegium*, new genus; and *Tropidelasma* Cooper and Grant, 1969.

### Genus *Streptorhynchus* King, 1850

PLATE 40: FIGURE 1

Small, subconical, usually broadly sulcate, outline subelliptical, weakly to strongly costellate, with strong fila and well-marked growth lines; hinge narrower than greatest width; pedicle valve interior devoid of dental plates or septa, teeth projecting forward from underside of interarea and continuing posteriorly toward apex as dental ridges flanking interior of pseudodeltidium; muscle marks normally obscure.

Brachial valve nearly flat to strongly convex, interarea short, not usually well marked; interior with strong cardinal process, notched or bifurcate distally, with 2 lobes longitudinally slit along posterior, which bear minute serrations; erismata fused to underside of cardinal process, forming inner surface for deep, circular, or slotlike sockets; lateral ends of dentifers fused to posterior wall of valve, producing shallow socket just inside hinge line.

TYPE-SPECIES.—*Terebratulites pelargonatus* Schlotheim (1816:28-29, pl. 8: figs. 21-24).

TYPES.—Figured specimen: YPM 27901.

DISCUSSION.—*Streptorhynchus* is distinguished from *Diplanus* Stehli (1954) by its different and more regular ornament, weaker growth lamellae, lack of well-developed brachial interarea and pitted umbo, smaller hinge teeth, unthickened lateral interior parts of pedicle interarea, much narrower median arch in pseudodeltidium, and by the small flanking arches of pseudodeltidium that mark the

paths of forward growth of the hinge teeth. Normally the shell of *Streptorhynchus* is thinner than that of *Diplanus*. *Diplanus* has no development of erismata.

*Streptorhynchus* differs from *Kiangsiella* Grabau and Chao (1927), which also is devoid of internal plates, by the lack of plications in the shell.

We have not seen any specimens in the Glass Mountains or Guadalupe Mountains that conform precisely to the generic diagnosis of *Streptorhynchus*, perhaps because all of these American localities are older than the Upper Permian (Zechstein) in which the type-species occurs.

*Streptorhynchus perattenuatum* Girty

See *Tropidelasma perattenuatum*.

*Streptorhynchus gregarium* Girty

See *Tropidelasma gregarium*.

*Streptorhynchus undulatum* R. E. King

See *Tropidelasma undulatum*.

*Chelononia*, new genus

Medium size, pyramidal, pedicle valve elongated; flatly convex to slightly concave in profile; hinge narrower than greatest width near midvalve; auriculate; pseudodeltidium strongly arched, brachial valve strongly convex, and not medially depressed; chilidium short; anterior commissure faintly sulcate. No brachial valve interarea. Surface marked by costellae of unequal size crossed by fine concentric fila.

Pedicle valve interior without dental plates; teeth long and slender; dental ridges not greatly thickened. Muscle field lightly impressed.

Brachial valve interior with large forked cardinal process supported by long, strong erismata. Dentifer a small ridge forming the inner socket wall; erismata forming blunt points extending anterolaterally; muscle field thickened and with a thick, low myophragm.

TYPE-SPECIES.—*Chelononia neali*, new species.

DIAGNOSIS.—Elongate Streptorhynchidae.

COMPARISON.—This genus is distinguished at once from *Streptorhynchus* (sensu stricto) by its

elongate pedicle valve and auriculate cardinal extremities. Externally it is like *Tropidelasma* in having an elongated pedicle valve, but it differs in the type of pseudodeltidium, which is flat in *Tropidelasma*. The cardinal process of *Chelononia* is different in having a more prominent dentifer and more elaborate erismata.

DISCUSSION.—This genus is rare in the Glass Mountains but one locality, USNM 727e, yielded a fair number of specimens. The elongate form and auriculate cardinal extremities are its chief exterior marks. The pseudodeltidium is strongly rounded from the margin of the delthyrium and thus unlike that of *Tropidelasma*. The chilidium is similar to that in other Permian Orthotetidinina in having a narrow space between it and the shell body. In *Chelononia* the chilidium does not affect the form and shape of the pseudodeltidium.

The cardinal process is the most conspicuous interior feature of the brachial valve. It is not as ponderous as that of *Meekella*, but it is long and strong with well-developed erismata, much more so than in *Streptorhynchus*. The socket is formed by the ridgelike dentifer, which is located on the long sloping side of the erisma. No fulcral plate is present in *Chelononia*. The erismata are bluntly pointed just anterior to the dentifer and probably serve the same purpose as the crura in the rhynchonellids to attach the body wall. The myophores are slits in the ends of the moderately divergent prongs of the cardinal process.

This genus has been seen only in the Neal Ranch Formation.

*Chelononia neali*, new species

PLATE 126: FIGURES 1-47

Large for genus, outline triangular, length slightly greater than width. Maximum width anterior to midvalve; sides variable; posterolateral part nearly straight but anterolateral part narrowly rounded. Hinge narrow, about half width of large specimens; cardinal extremities slightly auriculate. Interarea apsacline, fairly long but narrow, generally flat; pseudodeltidium narrow, moderately arched. Anterior commissure broadly and gently sulcate. Surface costellate, costellae low, usually alternating strong and fine; 11 costellae in 5 mm at front margin of holotype; 12 in same distance at front of specimen 19 mm long.

Pedicle valve faintly convex to nearly flat in lateral profile; anterior profile a broad gentle arch with moderately steep sides. Beak ridges sharp, strongly overhanging posterolateral margins. Umbonal region slightly swollen medially to margin where faint suggestion of ventrad folding can be detected. Flanks slightly swollen, sides falling off abruptly and steeply.

Brachial valve evenly and moderately convex in lateral profile, broadly convex in anterior profile with median depression at the top of dome. Posterolateral extremities deflected to form small ears; umbonal region fairly strongly swollen. Sulcus

originating on umbo deepening and widening to anterior margin.

Pedicle valve interior with long, thick, narrow teeth, dental ridges, low but strong. Diductor field narrowly flabellate.

Brachial valve interior with chilidium modified; cardinal process long-shafted with myophore prongs well separated but subparallel or slightly divergent. Sockets wide, bounded internally by dentifers; cardinal process buttressed by strong erismata. Adductor field deeply entrenched, heart-shaped, myophragm low.

MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| USNM 727e          |   |  |                                |                              |                                   |                  |
| 152646a            | 10.8  | 8.6  | 9.0                            | 5.1                          | 3.2                               | 4.3              |
| 152646b            | 14.1  | 12.0   | 12.6                           | 8.0                          | 4.0                               | 5.0              |
| 152646c            | 14.5  | 12.5   | 14.0                           | 8.3                          | 3.2                               | 7.2              |
| 152646d            | 18.8  | 15.3   | 16.5                           | 9.8                          | 4.4                               | 8.2              |
| 152646e            | 20.8  | 17.0   | 19.8                           | 10.7                         | 6.4                               | 10.7             |
| 152646f (holotype) | 24.6+   | 20.0   | 24.0                           | 33.0?                        | 8.4                               | 12.2             |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2 and 4).

LOCALITIES.—Bed 2: USNM 701; bed 4: 727e.

DIAGNOSIS.—Large *Chelononia* with hinge slightly more than half the maximum width.

TYPES.—Holotype: USNM 152646f; figured paratypes: 152646a, b, d, e, g–m; measured paratypes: 152646a–e; unfigured paratypes 152646c.

COMPARISON.—This species suggests *Chelononia straminea*, new species (= *Streptorhynchus pyramidale* R. E. King; not Newberry, 1861) but its interarea is much shorter, the costellae are not so crowded, and the proportions are entirely different.

DISCUSSION.—Two features of considerable interest in this species are the development of the chilidium and the nature of the dentifer as defined herein. The chilidium in young shells is divided into two parts, each consisting of a narrow arch on each side of the midpoint of the hinge and separated by a narrow groove. As growth proceeds in a ventrad direction, the chilidial plates grow out over the cardinal process shaft for a considerable distance and the ventrad face is inserted against the distal interior face of the pseudodeltidium. The part of the chilidium growing over

the cardinal process shaft is smooth because in opening and closing of the shell the surfaces moved against one another. The chilidium grows ventrally for a considerable distance and forms a thick boss at the posterior that tapers anteriorly along the cardinal process shaft. The depression between the two branches is never obliterated and leads to the cleft between the myophore prongs. On the exterior the chilidium retains its concentrically layered appearance, but it may be deeply inset because of posterior shell growth over the inner surface. In such cases the expanded chilidium overhangs the hinge, and a deep gap appears between the hinge line and the chilidium. The deep groove in the chilidium appears not to affect the pseudodeltidium, which is moderately and smoothly arched without the median groove seen in some of the derbyias and *Bothrostegium*.

The dentifer as defined herein is unusually well developed in this species. It appears as a strong oblique ridge located on the flank of the cardinal process and buttressed by the erisma. This plate forms the inside of the socket against which the outside of the tooth rested. Additional articulation in the older specimens was provided by a



growth of adventitious shell from the distal edge of the chilidial plate growing laterally and joining the hinge across the proximal end of the socket. The erisma is strongly developed in this species, and an extension of it protrudes anterolaterally to give the appearance of a brachial process as it would probably be interpreted.

The species is named for Bill Neal, owner of the Bill Neal Ranch and proud possessor of the type sections of the Wolfcamp Series and the Neal Ranch Formation.

*Chelononia straminea*, new species

PLATE 95: FIGURES 1-22

*Streptorhynchus pyramidale* R. E. King, 1931:50, pl. 4: figs. 7-9 (not fig. 10) [not *Streptorhynchus pyramidalis* Newberry, J. S., 1861:126, pl. 2: figs. 11-13].

Elongate, flatly conical, rectimarginate to slightly sulcate; outline lyre-shaped, with growth of flared hinge producing acute beak ridge along pedicle valve edge; valves unequally convex but subequal in depth; costellae strong, fasciculate, interrupted by prominent growth laminae widely and evenly spaced over anterior three-fourths of shell. Hinge from one-third to one-half total width of shell. Costellae numbering 8-10 in 5 mm at anterior margin.

Pedicle valve flattened, with extremely long triangular interarea bisected by wide and high arched pseudodeltidium, about one-fourth as wide as interarea; interarea making gentle angle with plane of commissure slightly apsacline. Brachial valve with greatest convexity near beak, hinge flaring and auriculate as on pedicle valve; sulcus shallow, wide, originating posterior to midvalve.

Pedicle valve interior broadly concave and shallow; teeth long, strong, projecting forward from underside of interarea, forming strong dental ridges along delthyrial edge. Muscle marks faint, elongate, lobate, occupying low depression or callosity on floor and sides of valve, bisected by low myophragm; adductor marks lobate, straddling myophragm; diductor marks longitudinally striate, extending up onto sides of narrow beak cavity.

Brachial valve interior with short, stout, bifid cardinal process, each prong longitudinally slit and with fine serrations lining edges of slit; dentifera narrow ridges defining wide hinge sockets; erismata extending short distance along sides of valve, outlining posterolateral margins of muscle area. Muscle area bilobate, excavate, divided by low myophragm, each scalloped at edges, with palial marks extending radially from them as grooves and ridges.

MEASUREMENTS (in mm).—

|           | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-----------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701d |                            |                             |                  |                |                     |           |
| 147883a   | 38.9                       | ?                           | 16.5             | 11.3           | 21.0                | 11.6      |
| 147883b   | 41.0+                      | 22.0                        | 25.6*            | 11.4           | 19.6+               | 18.7      |
| 147883c   | 31.0                       | 17.8                        | 19.2             | 8.8            | 14.8                | 12.3      |
| 147884    | 41.3                       | 24.4                        | 22.0             | 14.4           | 19.6                | 17.6      |
| 147885    | ?                          | 20.2                        | 24.0             | 12.9           | ?                   | 9.0       |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2, 9-14 of P. B. King).

LOCALITIES.—R. E. King 93; USNM 701d, 701h.

DIAGNOSIS.—*Chelononia* with exceptionally long pedicle valve.

TYPES.—Holotype: YPM 11392a; figured paratypes: YPM 11392b, c; figured hypotypes: USNM 147883b, c, 147884.

COMPARISON.—*Chelononia straminea* is characterized by its thatchlike ornamentation, lyre-shaped outline, and by the flange along the pedicle beak

that is produced by forward growth of the flaring hinge. This is the only species in the Glass Mountains that has a narrow median sulcus, although *Tropidelasma culmenatum* Cooper and Grant may have a broad and shallow sulcus. The pedicle valve of *C. straminea* is a flat cone with a very gentle, obtuse angle between the plane of commissure and the interarea. It is similar in this respect to *Streptorhynchus pelargonatum* (Schlotheim), the type-species of that genus, from which *C. straminea* may

be distinguished by its great length, ornament, and flaring hinge.

*Chelononia straminea* differs from *C. neali* in having a much more elongated pedicle valve.

DISCUSSION.—*Chelononia straminea* is rare in the Glass Mountains. It has been found only at three localities; however, it is very distinctive, and cannot be confused with other species.

R. E. King (1931:50) declared that the shell is very thick. Our specimens were prepared by treatment in acid and may not show the true thickness of shell throughout, probably because of incomplete silicification. King's specimen of a brachial valve (1931, pl. 4: fig. 7) is completely silicified and quite thick. Our description of the muscle area in the brachial interior is based largely on study of that specimen.

Aside from differences in size and proportion that are due to growth, this species varies within rather narrow limits, in comparison with variation in other species of Derbyiacea from this area. The beak of the pedicle valve is regular and undistorted in some individuals, but it is slightly bent or twisted laterally or dorsally in others. Its length is variable, ranging from a blunt point to a long and narrow projection, with the proportions mentioned in the description of the species. The brachial valve varies but little, mostly in the depth of the median sulcus, which never is very deep.

### *Bothrostegium*, new genus

[Greek *bothros* (trench) + *stegion* (roof, dim)]

Small, commonly attached Derbyiacea having conical pedicle valve and brachial valve of varying convexity, usually low. Anterior commissure usually slightly sulcate or rectimarginate. Pedicle valve interarea usually apsacline but varying to procline; pseudodeltidium large and convex, marked by impressed line along middle. Surface finely costellate; growth lamellae usually distant.

Pedicle valve interior with large, thick teeth but low, thick dental ridges. No other features developed.

Brachial valve with large well-developed chilidium with median cleft occupied by narrow ridge on underside of pseudodeltidium. Cardinal process with deeply incised, usually short prongs; dentifer short, erismata short. Adductor field subcircular, short ridge or boss at anteromedian extremity.

TYPE-SPECIES.—*Bothrostegium derbyoideum*, new species.

DIAGNOSIS.—Small Streptorhynchidae with grooved pseudodeltidium and large chilidium.

COMPARISON.—This genus is essentially a *Derbyia* without dental plates. The cardinalia are like those of *Derbyia* except that they have only short erismata. The pseudodeltidium, with its impressed groove down the middle, is like that of *Derbyia*. The genus differs from *Streptorhynchus*, which it resembles in size and outline, by the presence of the impressed line on the pseudodeltidium and a more prominently developed chilidium. In size and general form, *Bothrostegium* is like *Diplanus*, but that genus is lamellose and has a much longer interarea on the brachial valve but no impressed line on the pseudodeltidium. Internally the cardinalia are unlike those of *Diplanus* in having laterally extended erismata like those of *Streptorhynchus*.

DISCUSSION.—The chief feature of interest in the pedicle valve of this genus is the pseudodeltidium, which is so much like that of *Derbyia*, with an impressed line along the crest. The line is caused by an indentation in the median part of the chilidium into which the pseudodeltidium grows in the younger stages. As the pseudodeltidium grows, so also does this slight trough, which is expressed as a ridge under the small depression in the top.

The brachial valve of *Bothrostegium* does not develop like that of *Diplanus*, although they have much in common. In the latter, the chilidium is advanced in a ventrad direction along with the interarea as the shell enlarges. In *Bothrostegium*, this does not take place; consequently, the interarea remains very short while the chilidium grows dorsally to adapt to the expanding shell. The cardinal process is built against the inside of the chilidium. As the chilidium grows, its central cleft deepens and this becomes reflected in the median trough of the pseudodeltidium of the opposite valve. In *Diplanus*, on the other hand, the groove in the chilidium is not deepened, and, in many cases, it is less pronounced in the late stages of adult growth.

### *Bothrostegium compactum*, new species

PLATE 62: FIGURES 22–36

Small, thick shelled, elongate rectangular in outline, pedicle valve flattened, misshapen, conical,

brachial valve transversely subrectangular; hinge wide, nearly equal to maximum width (near midvalve or slightly anterior to it); sides gently rounded; anterolateral extremities narrowly rounded; anterior broadly convex to faintly emarginate. Interarea long, generally flat, occasionally convex, apsacline, strongly convex wide pseudodeltidium marked medially by impressed line. Surface finely costellate, growth lamellae distant.

Pedicle valve triangular in lateral profile, long side usually flat but also weakly convex to faintly concave. Anterior profile broadly and gently convex. Umbonal region usually convex, commonly narrowed and passing into broadly flattened to slightly convex median region; lateral slopes short but very steep.

Brachial valve evenly and gently convex in lateral profile, broadly, evenly, and moderately convex in anterior profile; umbonal region scarcely swollen; median region moderately inflated with short anterior and lateral slopes. Sulcus shallow, narrow, poorly defined, originating near midvalve.

Pedicle valve interior with long, thick teeth but low, thick dental ridges. Pseudodeltidium strengthened medially by a thickening on inner, concave surface. Muscle region not defined; no myophragm developed.

Brachial valve interior with short, thick cardinalia; chilidium well developed, medially divided; cardinal process with short prongs deeply incised. Dentifer narrow. Adductor field small, deep, circular, anterior median myophragm thick.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| 152599a            | 7.8                        | ?                           | 7.5              | 7.5            | 4.5                 | 3.7       |
| 152599b (holotype) | 8.7                        | ?                           | 8.1              | 7.9            | 4.7                 | 4.3       |
| 152599c            | 8.7                        | ?                           | 7.3              | 6.4            | 3.4                 | 3.2       |
| 152599d            | 7.8                        | ?                           | 6.1              | 5.0            | 3.3                 | 3.2       |
| 152599e            | ?                          | 6.8                         | 8.2              | 6.4            | ?                   | 2.5       |
| 152599f            | ?                          | 5.6                         | 5.9              | 6.0            | ?                   | 1.9       |
| 152599g            | ?                          | 4.8                         | 6.4              | 6.0            | ?                   | 1.9       |
| 152599h            | ?                          | 4.0                         | 5.5              | 5.0            | ?                   | 1.4       |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703c.

DIAGNOSIS.—Small, thick-shelled, compressed, conical *Bothrostegium*.

TYPES.—Holotype: USNM 152599b; figured paratypes: 152599a, e, i, j; measured paratypes 152599c, d, f–h.

COMPARISON.—This species is thicker shelled, smaller, and more compressed than *B. derbyoideum*, new species. It is intermediate in size between the latter and *B. pusillum*, new species, but it is larger, more uniform, as regards the interarea, possesses a ridge or boss anterior to the adductor field in the brachial valve, and the cardinalia are not so strongly compressed laterally as those of *B. pusillum*.

*Bothrostegium derbyoideum*, new species

PLATE 62: FIGURES 5–14; PLATE 63: FIGURES 1–46

Small in size but fairly large for genus, variable, adults usually longer than wide but juveniles wider than long. Pedicle valve subconical; brachial valve usually moderately to flatly convex; hinge approximately equal to midwidth or slightly alate; sides gently rounded; anterior broadly rounded. Anterior commissure faintly to moderately sulcate. Interarea broad, long, usually apsacline but varying to procline; usually flat but occasionally curved and with fairly strongly convex pseudodeltidium bearing median impressed line. Surface finely costellate; growth lamellae distant.

Pedicle valve triangular in profile, long side flat to slightly concave; anterior profile broadly but moderately convex, usually slightly humped medially. Umbonal and median regions longitudinally swollen; lateral slopes steep; cardinal extremities slightly deflected.

Brachial valve gently convex in lateral profile and most convex in umbonal region; anterior profile

broadly and gently convex. Umbonal region gently swollen; median region forming shallow and poorly defined sulcus that produces a broad ventrad wave of anterior commissure. Cardinal extremities somewhat flattened. Posterolateral slopes short and gentle.

Brachial valve gently convex in lateral profile and most convex in umbonal region; anterior profile broadly and gently convex. Umbonal region gently swollen; median region forming shallow and poorly defined sulcus that produces a broad ventral

wave of anterior commissure. Cardinal extremities somewhat flattened. Posterolateral slopes short and gentle.

Pedicle valve interior with strong, thick teeth and low dental ridges. Muscle scars not impressed, no myophragm developed.

Brachial valve interior with moderately long cardinal process with fairly deeply incised prongs; dentifers broad with short laterally extended supporting plates. Chilidium well developed, deeply indented medially.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 721y          |                            |                             |                  |                |                     |           |
| 152595a            | 8.2                        | 7.4                         | 9.6              | 8.4            | 5.0                 | 8.2       |
| 152595b            | 11.8                       | 10.0                        | 12.2             | 10.5           | 7.2                 | 10.5      |
| 152595c            | 7.2                        | 6.9                         | 8.3              | 6.9            | 3.7                 | 6.4       |
| 152595d            | 7.1                        | 6.4                         | 8.3              | 7.8            | 4.6                 | 5.8       |
| 152595e            | 6.4                        | 6.0                         | 8.2              | 8.2            | 3.7                 | 4.9       |
| 152595f            | 6.0                        | 4.8                         | 6.8              | 6.2            | 4.0                 | 5.0       |
| 152595g            | 4.7                        | 4.4                         | 5.6              | 4.7            | 3.7                 | 4.1       |
| USNM 721t          |                            |                             |                  |                |                     |           |
| 152596a (holotype) | 12.3                       | 9.1                         | 10.5             | 8.7            | 6.4                 | 7.3       |
| 152596b            | 12.0                       | 8.7                         | 10.5             | 8.0            | 5.8                 | 7.9       |
| 152596c            | 10.8                       | 9.1                         | 10.2             | 7.8            | 5.5                 | 9.5       |
| USNM 724b          |                            |                             |                  |                |                     |           |
| 152597a            | 6.3                        | 5.7                         | 7.3              | 6.4            | 3.7                 | 5.8       |
| USNM 721w          |                            |                             |                  |                |                     |           |
| 152598a            | 10.6                       | 8.7                         | 10.0             | 7.8            | 3.7                 | 6.5       |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 710u, 720d, 721t, 721w, 721y, 724b.

DIAGNOSIS.—Fairly wide-hinged *Bothrostegium* with thin shell and moderately convex brachial valve.

TYPES.—Holotype: USNM 152596a; figured paratypes: 147891a–c, 152595a, b, d, 152596c, d, 152597a, 152598b, 153338; unfigured paratypes: 152595c, e–g, 152596b, 152598a; measured paratypes: 152595a–g, 152596b, c, 152597a, 152598a.

COMPARISON.—This species is larger and has a thinner shell than either *B. pusillum*, new species, or *B. compactum*, new species. The brachial valve of *B. pusillum* is generally more convex than that of *B. derbyoideum*, and the cardinalia are more laterally compressed in the former. The hinge of *B. compactum* is wide and the valves slightly alate as in *B. derbyoideum*, but the former species is not

so deep and the cardinalia of the two are unlike. Furthermore, *B. compactum* has a thick median boss anterior to the adductor field in the brachial valve.

*Bothrostegium pusillum*, new species

PLATE 118: FIGURES 8–21

Small for genus, thick shelled, commonly distorted, subconical, usually slightly longer than wide; maximum width usually anterior to mid-valve; sides unevenly rounded; hinge narrower than greatest width; cardinal extremities slightly alate; interarea long, commonly convex, usually strongly to moderately apsacline pseudodeltidium moderately wide, strongly convex, marked medially by deeply impressed line. Brachial valve interarea short, not strongly developed. Surface costellate, about 3 costellae per mm at anterior of large specimens; lamellae poorly developed.

Pedicle valve triangular in profile, ventral side forming hypotenuse of the triangle, varying from faintly convex to faintly concave but usually nearly flat; anterior profile broadly rounded. Umbonal region narrowly rounded; medial region usually flattened; beak ridges strong; anterior slope long, moderately steep; flanks short and steep.

Brachial valve fairly evenly and moderately convex in lateral profile, anterior profile broadly and fairly evenly convex; umbonal region slightly swollen; median region inflated with flanks and anterior slope fairly steep, the former steeper. Median re-

gion marked anteriorly by shallow, poorly defined sulcus.

Pedicle valve interior with long, thick, bluntly pointed teeth and thick dental ridges; muscle marks and septa not impressed or developed.

Brachial valve interior with thick and ponderous cardinalia and deep, open sockets; cardinal process short; prongs not elongated or widely separated; dentifers elongated, narrowly divergent and supported laterally by short erismata. Adductor scars not clearly visible and myophragm only slightly developed.

MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| 152594a (holotype) | 4.7   | 3.8  | 4.6                            | 3.8                          | 3.5                               | 4.1              |
| 152594b            | 5.1   | 4.7  | 5.5                            | 4.4                          | 2.8                               | 3.8              |
| 152594c            | 5.0   | ?  | 4.2                            | 3.7                          | 3.9                               | 3.2              |
| 152594d            | 4.4   | ?  | 4.7                            | 3.7                          | 2.8                               | 3.3              |
| 152594e            | 6.4   | ?  | 6.2                            | 4.6                          | 3.0                               | 3.2              |
| 152594f            | 5.3   | 3.8  | 4.4                            | 3.5                          | 3.2                               | 5.2              |
| 152594g            | 5.6   | 4.2  | 5.5                            | 4.3                          | 2.8                               | 3.7              |
| 152594h            | 6.7   | ?  | 7.3                            | 5.3                          | 4.8                               | 4.6              |
| 152594i            | ?   | 3.9  | 4.4                            | 3.3                          | ?                                 | 1.6              |
| 152594j            | ?   | 3.7  | 4.6                            | 4.0                          | ?                                 | 1.7              |
| 152594k            | ?   | 4.3  | 5.3                            | 4.2                          | ?                                 | 1.8              |
| 152594-l           | ?   | 5.3  | 6.0                            | 4.7                          | ?                                 | ?                |
| 152594m            | ?   | 5.0  | 6.6                            | 4.2                          | ?                                 | 2.2              |
| 152594n            | ?   | 6.4  | 7.5                            | 5.3                          | ?                                 | 2.5              |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 722e.

DIAGNOSIS.—Small, thick-shelled *Bothrostegium* with poorly defined lamellae and thick narrow cardinalia.

TYPE.—Holotype: USNM 152594a; figured paratypes: 152594b, e, j, n; measured paratypes: 152594b–n; unfigured paratypes: 152594a, c, d, f–n.

COMPARISON.—This species is most like *B. compactum*, but it differs in having a narrower hinge and stronger costellae. It differs from *B. derbyoides* in the same features.

Genus *Tropidelasma* Cooper and Grant, 1969

*Tropidelasma* Cooper and Grant, 1969:3.

Small to moderately large, variable in shape and outline from triangular to elongate triangular, valves very unequal. Pedicle valve subconical,

elongate and convex, brachial valve short, faintly to strongly convex and usually elliptical to circular in outline. Hinge narrower than greatest width (usually near midvalve). Anterior commissure rectimarginate to strongly sulcate. Surface finely costellate. Shell substance pseudopunctate.

Pedicle valve with long interarea marked medially by flat to slightly convex pseudodeltidium anteriorly notched, midline narrowly folded to form elongate monticulus. Teeth strong, forming thick ridges under delthyrial margin. Area under palintrope lateral to teeth notched to form a narrow cavity. Muscle field poorly defined and lightly impressed. Anterior margin very finely costellate.

Brachial valve with short, inconspicuous interarea; chilidium vestigial, forming medial boss or node at midvalve; cardinal process large, bilobed, lobes long and slender and slit medially on the posterior surface. Sockets narrow and deep; dentifers small, obscure, forming ridge on sloping sur-



face of the cardinal process shaft. Outside of socket bounded by a small oblique ridge. Adductor field rounded, divided medially by a slender often elevated, serrated myophragm. Erisma gradually being eliminated, often buried in adventitious shell tissue.

**TYPE-SPECIES.**—*Tropidelasma culmenatum* Cooper and Grant (1969:3, pl. 1: figs. 27–29).

**DIAGNOSIS.**—Elongate streptorhynchid brachiopods having a flat keeled pseudodeltidium, finely costellate ornament, remnantal brachial valve interarea with vestigial chilidium.

**COMPARISON.**—*Tropidelasma* differs from *Cheilononia*, which it resembles in shape by the absence of cardinal aurications, the flat pseudodeltidium with monticulus, and the greater extension of the cardinal process shaft. *Tropidelasma* differs from *Streptorhynchus* in shape, ornament, the development of the pseudodeltidium, greater development of the cardinal process, and failure to develop erismata except spasmodically.

**DISCUSSION.**—In studying the streptorhynchiform brachiopods in the Glass Mountains, it was noted that the pseudodeltidium of some of the species deviated from the kind seen in the type-species of *Streptorhynchus*. The variations recorded in this structure also pointed to some differences in the cardinalia of the brachial valves of the Glass Mountains species. The details of the pseudodeltidium of many of the Glass Mountains species are more like those of *Meekella* than of *Streptorhynchus*.

*Tropidelasma* has the general expression of streptorhynchid brachiopods with a large pedicle valve, usually with a much elongated beak. The brachial valve is lidlike and is usually fairly convex. The shell was attached by the pedicle valve. The point of attachment was often rather small, and many specimens must have broken from their natal moorings and lived loose on the sea bottom. Specimens have been found in clusters of attached valves, and others have been found cemented in clusters with *Derbyia*, *Geyerella*, or *Meekella*.

The exterior surface of *Tropidelasma* is covered by fine costellae that are interrupted by growth lamellae. The costellae in some species are closely crowded but more distant in others. No regularity in the spacing of the lamellae has been seen, and in many specimens they are closely crowded at the anterior.

The most significant and perhaps interesting morphological feature of this genus is the interarea of both valves and their deviation from *Streptorhynchus*. The interarea of *Tropidelasma* is usually an elongated triangle with a narrow base and a greatly elongated apex. The pseudodeltidium is the prominent part of this structure. As viewed between the teeth, it is not an arch but a flat plate lying on the inside edge of the teeth. Its midline is narrowly arched or keeled, the keel running from beak to anterior end, where it is narrowly notched. The keel, now called monticulus, corresponds to a protruberance on the midline of the cardinal process. The pseudodeltidium is buttressed or welded to solidity by deposition of adventitious shell on its under side and on the sides of the dental ridges.

It is interesting to note that *Tropidelasma* does not have a perideltidial area, a feature common on *Meekella*, *Derbyia*, and several other genera. Another feature is the conspicuous socket on the outside of each tooth, just on the underside of the palintrope. This socket is more conspicuous in some species than in others, but most of them have it. The sockets may be created by the movement of the brachial valve hinge in opening and closing the valves, and it articulates with the ridge or "tooth" often bounding the outside of the socket in many species.

The cardinalia of the brachial valve are welded into a solid piece, the component parts of which are difficult to identify. The cardinal process has two prongs, the upper or posterior side of each prong bearing a deep slit serrated on the sides in which the muscles were inserted. The prongs of the fork are closely welded in some specimens, but, in others, they are much elongated and divergent. The posterior face of the cardinal process is narrowly curved and ends in a small bilobed knob. The curved face of the cardinal process is marked medially by a narrow groove representing the dividing channel between the cardinal process lobes. This groove is continued onto the knob and bisects it. This small knob is inserted under the monticulus of the pseudodeltidium, the monticulus being the growth track of this projection. The knob is thought to be a remnant of the chilidium, which otherwise is not developed. Furthermore, the interarea and palintrope of this valve are re-

duced to small, widely triangular areas with obtusely angular apex.

The shaft of the cardinal process makes a long double-barreled extension with a median groove on the posterior side. On the opposite side this is a smooth concave trough, the sides of which are composed of a plate extending anterolaterally and probably representing the brachiophore or dentifer. The anteroventral edge of this plate is narrowly rounded or extended as a small point that might suggest a crus. These oblique extensions grow in a dorsad direction, extending under the overhang of the hinge to attach to the valve floor. The extensions appear to be reduced erismata, but in old shells they are almost completely buried by adventitious shell and the cardinalia thus suggest those of the Schuchertellidae. A lateral thickening often simulates erismata in some specimens.

The musculature is not clear on any of the Glass Mountains silicified specimens. But a strong serrated septum is present at the posterior under the cardinal process of well-preserved specimens. In *T. gregarium* (Girty) it is irregular and may take the form of a point extending anteroventrally at the posterior end of the septum.

*Tropidelasma* is common only locally, where it is an important member of bioherm assemblages. This is true of *T. culmenatum* and *T. rhamphodes*, which are found clustered with other derbyiacean or cemented aulostegids such as *Scacchinella*. Specimens from the Word Formation are rare and no evidence points to them having lived in a biohermal assemblage.

### *Tropidelasma anthicum*, new species

PLATE 59: FIGURES 1-36; PLATE 60: FIGURES 1-39

Widely conical, semicircular to transversely sub-elliptical in outline, rectimarginate, ornamented by

weak radial costellae interrupted by moderately strong growth laminae; hinge narrower than maximum width of shell. Pedicle valve normally flared toward margin, interarea flat, moderately long, commonly slightly twisted or bent, transversely scored by straight growth lines, bisected by pseudodeltidium with narrow, low, indistinct median arch and 2 lower lateral arches marking paths of growth of hinge teeth. Brachial valve moderately to strongly convex, with tendency for most strongly convex valves to be distorted, umbo overhanging pedicle interarea; growth laminae more closely spaced toward margin.

Pedicle valve interior with short blunt hinge teeth projecting forward from beneath interarea, extending posteriorly as low convergent ridges along sides of pseudodeltidium, ridges becoming lower toward apex of beak, disappearing anterior to apex in some individuals. Muscle marks faint, occupying large part of floor of delthyrial chamber, consisting of longitudinal striae that may be subdivided by low, rounded median ridge. Anterior and lateral margins of valve minutely radially serrate.

Brachial valve interior shallow to deeply cup-shaped; cardinal process long, wide, stout, and with shallow to deeply bifurcated notch and with each branch longitudinally split and having fringelike serrations in slots; splits and bifurcation partly or completely fused with growth to produce slight grooves along length of process. Dentifers fused to sides of cardinal process, projecting very slightly or not at all, forming inner slope for round to slot-shaped sockets. Lateral thickening of secondary shell outlines part of muscle area, in others diverging widely parallel to hinge, producing inside the margin a shallow groove just anterior to hinge. Muscle area depressed, lying under arch of cardinal process, often bisected by short, low myophragm; margins of valve finely serrate radially.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 706b          |                            |                             |                  |                |                     |           |
| 147861a (holotype) | 27.3                       | 22.2                        | 24.9             | 17.5           | 14.3                | 27.2?     |
| 147861b            | 26.4                       | ?                           | 21.6             | 16.9           | 14.4                | 13.7      |
| 147861c            | 17.7                       | ?                           | 20.0             | 14.6           | 16.5                | 18.0      |
| 147861d            | ?                          | 17.2                        | 21.5             | 15.0           | ?                   | 7.7       |
| 147861e            | ?                          | 20.0                        | 21.9             | 15.5           | ?                   | 10.0      |
| 147861f            | 10.4                       | ?                           | 9.6              | 6.4            | 5.4                 | 7.6       |
| USNM 706           |                            |                             |                  |                |                     |           |
| 147852a            | 26.5                       | ?                           | 26.7             | 19.7           | 15.0?               | 17.0      |
| 147852b            | 24.3                       | ?                           | 30.6             | 22.5           | 20.0                | 19.7?     |
| USNM 706c          |                            |                             |                  |                |                     |           |
| 147856             | 25.4                       | ?                           | 33.0             | 24.2           | 18.8                | 17.8      |

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, and Appel Ranch members; lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—China Tank: USNM 706c, 713, 726r, 733q; Willis Ranch: AMNH 506, USNM 706, 706e, 723t; lens: USNM 706b; Appel Ranch: USNM 715i, 722t, 727j.

DIAGNOSIS.—*Tropidelasma* of moderate size with narrowly conical, flaring pedicle valve and long stout cardinal process.

TYPES.—Holotype: USNM 147861a; figured paratypes: 147861b, d, e, g, 153555a, b, 153556, 153557a–c; measured paratypes: 147861b–f, 147852a, b, 147856; unfigured paratypes: 147861c, f; measured paratypes: 147861b–f, 147852a, b, 147856.

COMPARISON.—*Tropidelasma anthicum* is characterized by its moderately deep conical pedicle valve, which normally flares outward at the margin and bears a low, often indistinct monticulus on the pseudodeltidium and short hinge teeth that make only low and gently rounded ridges on the underside of the interarea. The brachial valve is moderately to strongly convex with a long cardinal process, which, in combination with brachiophores that are fused to its sides, forms a broad arch over the umbonal cavity.

This species most closely resembles *T. culmenatum*, the type-species, but it differs by its nonsulcate anterior, less convex brachial valve, shorter hinge teeth that make weaker internal ridges, less deeply conical, more widely flaring pedicle valve with flatly arched median ridge on the pseudodeltidium. These features plus its much weaker

growth lines also distinguish *T. anthicum* from *T. rhamphodes*, new species. It differs from *T. strobilum*, new species, by its much shorter and normally less distorted pedicle beak and especially by its short hinge teeth that make weak internal ridges. The somewhat more deeply bifurcate cardinal process, much less distinct, less bladelike dentifers, very low or absent brachial myophragm, and weaker hinge teeth distinguish *S. anthicum* from *T. gregarium* (Girty) of the Guadalupian (Bell Canyon Formation).

DISCUSSION.—The collection of *S. anthicum* is comparatively small, and, for this reason, may not contain the complete range of variation of the species. Most specimens conform to the pattern given in the description, but some do not have the flaring pedicle valve. These are similar in shape to *T. rhamphodes* and must be distinguished on the basis of features other than external shape (see "Comparison"). Some brachial valves of *S. anthicum* are so strongly convex that they grew irregularly, becoming distorted like the conical pedicle valve. Distortion normally involves the beak and hinge regions. The cardinal process is uniformly long and wide, making a broad arch by fusion with the dentifer. Sockets are round as in other species of the genus, but some are slotlike, converging posteriorly toward the convex side of the cardinal process.

The outline of *S. anthicum* normally is transverse, but some specimens are distorted so that the outline is elongate. Only distorted specimens have any folding of the margin, and even in them it is slight; the normal condition is rectimarginate.

*Tropidelasma corniculum*, new species

PLATE 58: FIGURES 28-36

Moderately large for genus, conical in outline and profile; hinge narrower than maximum width (just anterior to hinge); sides and anterior strongly rounded, brachial valve roundly elliptical. Anterior commissure rectimarginate. Interarea usually long broad and flat, pseudodeltidium depressed, nearly flat, marked by a narrow, monticulus and median notch. Brachial valve interarea fairly long. Surface finely and densely costellate.

Pedicle valve triangular in lateral profile, hypotenuse moderately convex; anterior profile roundly domed; pedicle valve strongly conical, one side flattened, anterior flaring widely; beak ridges

rounded. Umbonal region narrowly swollen, beak variable. Median region somewhat swollen; lateral slopes very steep.

Brachial valve moderately but unevenly convex, umbonal region most convex, anterior somewhat flattened. Anterior profile broadly and gently convex. Umbonal region strongly swollen, antero- and lateromedian regions flattened.

Pedicle valve interior with short, thick teeth and low, thick dental ridges. Muscle field and septa not developed.

Brachial valve with long forked cardinal process, prongs not strongly divergent. Sockets shallow. Dentifer broad and gently sloping. Myophragm low extending to about midvalve; adductor field lightly impressed.

## MEASUREMENTS (in mm).—

|                   | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720d         |                            |                             |                  |                |                     |           |
| 152592a           | 14.4                       | ?                           | 12.4             | 8.0            | 6.6                 | 6.6       |
| 152592b           | 13.4                       | ?                           | 14.0             | 9.7            | 5.1                 | 6.2?      |
| 152592c           | 14.4                       | ?                           | 14.3             | 7.2            | 4.1                 | 5.2       |
| 152592d           | 11.5                       | ?                           | 11.7             | 6.7            | 4.5                 | 5.6       |
| 152592e           | 12.3                       | ?                           | 14.6             | 9.4            | 6.0                 | 6.2       |
| 152592f           | 6.1                        | ?                           | 6.2              | 3.4            | 1.9                 | 2.5       |
| 152592g           | ?                          | 12.4                        | 15.6             | 11.5           | ?                   | 6.1       |
| 152592h           | ?                          | 11.2                        | 11.8             | 6.7            | ?                   | 3.8       |
| 152592i           | ?                          | 11.2                        | 12.7             | 9.1            | ?                   | 5.0       |
| 152592j           | ?                          | 10.0                        | 11.6             | 7.8            | ?                   | 3.5       |
| 152592k           | ?                          | 10.7                        | 11.0             | 6.5            | ?                   | 5.2       |
| 152592-l          | ?                          | 11.7                        | 12.3             | 7.8            | ?                   | 4.9       |
| 152592m           | 30.0+                      | ?                           | 32.2             | 25.0           | 22.0?               | 25.5      |
| 152592n           | 16.8                       | ?                           | 19.6             | 13.8           | 11.4                | 12.8      |
| 152592o           | 16.0                       | 14.8                        | 14.0             | 11.4           | 6.0                 | 12.3      |
| USNM 721z         |                            |                             |                  |                |                     |           |
| 152593            | ?                          | 27.1                        | 31.3             | 21.2           | ?                   | 9.8       |
| USNM 724d         |                            |                             |                  |                |                     |           |
| 153562 (holotype) | 45.0                       | 42.3                        | 46.7             | 30.5           | 21.9                | 37.0      |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503, USNM 700v, 703, 703a, 706f, 707f, 707e, 720d, 721j, 721t, 721z, 724c, 724d.

DIAGNOSIS.—*Tropidelasma* of fairly large size with rectimarginate anterior commissure and strongly inflated umbo on the brachial valve.

TYPES.—Holotype: 153562; figured paratypes: 152592m, 152593; measured paratypes: 152592a-o; unfigured paratypes: 152592a-l, n, o.

COMPARISON.—This species suggests *T. culmenatum*, the type-species, and *T. rhamphodes*, new species. It differs from the former in having a rectimarginate anterior commissure rather than the moderately strong fold of *T. culmenatum*. The Road Canyon species does not have the sinuate anterior and consequently longitudinal swollen median region of the pedicle valve that is prominent on the Neal Ranch species. *Tropidelasma corniculum* is more strongly umbonate dorsally than either *T. culmenatum* or *T. rhamphodes*. It also differs

from *T. rhamphodes* in having no anterior sulcus on the brachial valve although this is flattened without affecting the anterior commissure. It has a smaller and less elongated cardinal process with more flaring and less steep dentifer than in *T. rhamphodes*.

DISCUSSION.—This genus is fairly common in the Road Canyon Formation northwest of the Hess Ranch and on the east side of Gilliland Canyon, but most of the specimens in the latter location are immature. A few adult specimens have been found and the description is based on them. Some variation is seen in the ornamentation of the young, but that of the adults is insufficiently preserved to be sure that we are dealing wholly with variation rather than with differently ornamented species.

*Tropidelasma costellatum*, new species

PLATE 58: FIGURES 16–27

About medium size for genus, moderately to strongly elongated; pedicle valve a poorly formed cone, and brachial valve broadly elliptical in outline; sides usually somewhat narrowly rounded;

anterior commissure usually with narrow to broad ventrad wave. Exterior costellate, costellae of several sizes and intercalated, about 13 costellae of all sizes in 5 mm at front of adult.

Pedicle valve unevenly convex in lateral profile, the anterior half more strongly convex; anterior profile strongly convex and with steep sides. Beak small and narrow; interarea widening rapidly; pseudodeltidium with raised monticulus throughout its length, sides flattened only in anterior half; median region longitudinally swollen to form poorly defined fold. Attachment surface variable, usually large.

Pedicle valve interior with small teeth and low dental ridges. Not greatly thickened under palintrope.

Brachial valve moderately but fairly evenly convex laterally; moderately and broadly domed in anterior profile; umbonal region not strongly swollen; median region slightly inflated; lateral and anterior slopes gentle.

Brachial valve interior with long slender cardinal process, narrowly rounded, with moderate development of dentifers; myophragm threadlike.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| 147823a (holotype) | 15.1                       | 13.3                        | 15.5             | 11.8           | 13.5                | 13.5      |
| 147823b            | 14.5                       | 11.9                        | 14.7             | 8.0            | 6.8                 | 10.3      |
| 147823c            | 13.5                       | 10.3                        | 12.0             | 7.2            | 5.8                 | 9.4       |
| 147823d            | ?                          | 14.4                        | 17.8             | 11.2           | ?                   | 5.2       |

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member).

LOCALITY.—USNM 702d.

DIAGNOSIS.—*Tropidelasma* of moderate size with distant costellae.

TYPES.—Holotype: USNM 147823a; figured paratype: 147823d; unfigured and measured paratypes: 147823b, c.

COMPARISON.—The distant costellae separate this species from *T. gregarium* (Girty) and *T. curtum*, new species, which are nearest it in size.

DISCUSSION.—This is a rare species because only 12 specimens of it are known. These include an incredible range of variation, but all seem to have the same pattern of costellae. That this is a bioherm-dweller is clear because the specimens were taken

with the large *Heliospongia* and numerous other sponges at USNM 702d.

*Tropidelasma culmenatum* Cooper and Grant

PLATE 51: FIGURES 1–36; PLATE 52: FIGURES 1–32; PLATE 53: FIGURES 12–27; PLATE 58: FIGURES 15, 37–43

*Tropidelasma culmenatum* Cooper and Grant, 1969:3.

Large, conical, deeply or broadly sulcate, rarely rectimarginate; outline subtrigonal or transversely subelliptical; costellae weak, bifurcating fasciculate, growth lines slightly stronger, becoming more frequent toward margin, growth lamellae flat, not protruding. Pedicle valve beak deeply conical, commonly twisted or bent; interarea long, triangular,



bisected by pseudodeltidium with narrow monticulus and lower ridge on each side marking paths of growth of hinge teeth; interarea transversely scored by straight growth of hinge teeth; interarea transversely scored by straight growth lines; anterior slope of valve below sulcus forming ridge; broadly rounded in outline, concave in profile. Brachial valve moderately convex, deeply bowed anteriorly in sulcate specimens; hinge narrower than maximum width.

Pedicle valve interior with teeth protruding anteriorly from underside of interarea, extending posteriorly as strong, ridges along flanks of pseudodeltidium, converging toward apex. Muscle area slightly depressed; muscle marks consisting of faint longitudinal striae on valve.

Brachial valve interior with long, wide, bifurcate, posteriorly ridged cardinal process, ridge on process short, located near beak, making continuation of median ridge of pedicle pseudodeltidium; each branch of cardinal process cylindrical, with posterior longitudinally slit for part of length, edges of slit with fringelike serrations.

Brachial valve interior with dentifers fused to sides of cardinal process and to posterior wall of valve, forming wide arch over deep umbonal cavity and providing inner walls for deep hinge sockets; lateral terminations of dentifers form inside edge of shallow groove just anterior to hinge. Muscle area in umbonal cavity, poorly defined, divided by low, short myophragm; inner margin of valve radially serrate.

#### MEASUREMENTS (in mm).—

|                    | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|--------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 701h          |                                     |                                      |                          |                        |                             |                  |
| 147829a            | 50.5                                | 30.6                                 | 50.7                     | 45.5                   | 35.7                        | 35.0             |
| 147829b (holotype) | 40.5                                | 28.7                                 | 37.8                     | 34.3                   | 43.2                        | 47.0?            |
| 147829c            | 26.5                                | 25.0                                 | 27.9                     | 19.4                   | 12.0                        | 21.6             |
| 147829d            | 24.2                                | 18.6                                 | 21.5                     | 17.8                   | 19.7                        | 26.4             |
| 147829e            | 17.8                                | 14.4                                 | 16.3                     | 11.8                   | 15.6                        | 22.0             |
| 147829f            | 16.0                                | 16.0                                 | 18.6                     | 11.6                   | 10.0                        | 16.0             |
| 147829g            | 14.0                                | 9.0                                  | 9.7                      | 7.3                    | 7.0                         | 10.6             |
| 147829h            | 6.3                                 | 4.3                                  | 5.4                      | 4.6                    | 3.7                         | 4.0              |
| 147829i            | 3.3                                 | 3.3                                  | 3.2                      | 2.4                    | 2.1                         | 3.0              |
| 147829j            | 24.3                                | 17.0                                 | 21.6                     | 17.0                   | 15.3                        | 20.0             |
| 147829k            | 27.6                                | 22.3                                 | 30.4                     | 22.9                   | 15.2                        | 27.6             |
| 147838             | 15.3                                | 13.7                                 | 15.0                     | 11.4                   | 19.5                        | 24.3             |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 12–14).

LOCALITIES.—USNM 701, ?701a, 701c, 701d, 701g, 701h, 701k, 701v, 727d, 727e.

DIAGNOSIS.—Large, wide-hinged *Tropidelasma* with pedicle valve elongated and anteriorly geniculated.

TYPES.—Holotype USNM 147829b; figured paratypes: 147829a, c, e, h, i, k, l; figured hypotypes: 147838, 147839, 147842, 147865a, b, 147875, 153559a, b, 153560a–d; measured paratypes: 147829a, c–k, 147838.

COMPARISON.—*Tropidelasma culmenatum* is characterized by its subtrigonal to transverse outline, wide hinge, the geniculation of the anterior of the pedicle valve toward the dorsal side to produce a concave profile along the anterior slope, weak

costellae, and relatively flat growth lamellae. It most nearly resembles *T. rhamphodes*, new species, from which it is distinguished by the above features, most especially the concave anterior profile of the pedicle valve, subtrigonal outline of that valve, and the less protruding growth lamellae. The sulcus ridge distinguishes this species from *T. anthicum*, new species, and *T. strobilum*, new species, and the much larger size and weaker costellation differentiate it from *T. pygmaeum* Girty. The deeply conical pedicle valve distinguishes *Chelononia straminea*, new species (= *Streptorhynchus pyramidale* King), from similar European and Asian species that also are nearer *Streptorhynchus pelargonatum* Schlotheim. The more deeply conical pedicle valve, sulcate margin, subtrigonal outline,

and greater maximum size distinguish *T. culmenatum* from *T. gregarium* (Girty).

DISCUSSION.—No single diagnostic feature distinguishes *T. culmenatum* from *T. rhamphodes*, although difference in curvature of anterior profile most nearly approaches being diagnostic. Each species is variable and contains a few specimens that are almost intermediate morphologically. In some specimens of *T. culmenatum*, distortion of the pedicle beak has produced a convex profile in place of the normal geniculation and concave anterior slope. The margin of *T. culmenatum* ranges from deeply sulcate to nearly rectimarginate, but those that approach being rectimarginate are widely transverse. The pedicle beak and interarea may be shallow and broad or deep and slender, probably reflecting variety in place and mode of attachment to the substrate while the shell was living. As is typical of most West Texas species of this genus, very small specimens have relatively wide median arches. Normally, these appear after the interarea has attained a height of about 5 mm.

Two bioherms produced a large quantity of this species of all sizes making it possible to see how the species grew. An interesting feature of this species is the small attachment surface for such a large shell. A favorite site for its life is a recess in the large lamellar bryozoans that make up a fair part of some bioherms.

Most of the material of this species comes from the Neal Ranch Formation from beds 4–14 of P. B. King. We have specimens from USNM 701 that are from the upper 15 feet of the bed 2 or Gray Limestone of P. B. King, placed by Ross (1961) in the top of the Gaptank. We are unable to separate these specimens from the higher ones, perhaps because we have so few of them. It is evident, however, from the fact that a large *Tropidelasma*

(species 2) is known from the *Uddenites*-bearing Shale Member that this genus became established and flourished in Gaptank time.

### *Tropidelasma curtum*, new species

PLATE 58: FIGURES 1–14

Small for genus, slightly longer than wide, pedicle valve forming short, misshapen cone; brachial valve broadly elliptical. Sides rounded; anterior margin broadly rounded to subtruncate. Hinge narrower than midwidth, about three-fourths maximum width. Anterior commissure broadly and gently sulcate in adult. Surface costellae, narrower than interspaces, 3–4 occupying 1 mm at anterior. Growth lines producing a lamellar appearance to anterior.

Pedicle valve narrowly triangular in lateral profile; ventral side convex, anterior half having greater curvature; anterior profile broadly but fairly strongly rounded and with moderately steep sides. Interarea broad, pseudodeltidium flattened. Area of attachment small, confined to umbonal region. Anteromedian region swollen, forming poorly defined fold.

Brachial valve fairly strongly and evenly convex in lateral profile and gently domed with long moderately steep lateral slopes in anterior profile. Interarea fairly long and broad, prominent. Umbonal region not swollen. Anterior slope fairly steep.

Pedicle valve interior with small teeth and narrow, not thickened, dental ridges. Ridges ventrad to palintrope narrow. Muscles not impressed. Brachial valve interior with fairly long, narrow cardinal process with distal extremity not widely divergent. Sockets moderately deep; dentifers short. Myophragm small.

#### MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>maximum</i><br><i>width</i> | <i>hinge</i><br><i>width</i> | <i>interarea</i><br><i>length</i> | <i>thickness</i> |
|--------------------|---|--|--------------------------------|------------------------------|-----------------------------------|------------------|
| 152590a            | 17.3  | ?  | 17.4?                          | 12.4                         | 8.9                               | 8.0              |
| 152590b (holotype) | 15.5  | ?  | 13.9                           | 8.0                          | 4.6                               | 5.3              |
| 152590c            | 12.8  | ?  | 13.8                           | 10.5                         | 6.5                               | 6.3              |
| 152590d            | ?   | 12.4   | 14.5                           | 9.2                          | ?                                 | 5.3              |
| 152590e            | ?   | 8.9  | 10.5                           | 7.3                          | ?                                 | 3.9              |

STRATIGRAPHIC OCCURRENCE.—San Andres Formation.

LOCALITY.—AMNH B188–8.

DIAGNOSIS.—Small *Tropidelasma*, thick shelled,

with short, conical pedicle valve and brachial valve having a wide cardinal process.

TYPES.—Holotype: USNM 152590b; figured paratype: 152590d; unfigured measured paratypes: 152590a, c, e.

COMPARISON.—This is a small species and need be compared only with the species of similar moderate size. It is most like *T. gregarium* (Girty), but it differs in having a somewhat less elongated pedicle valve, thicker shells, generally smaller size, and more regular costellae. It is smaller and more regularly formed and has different costellation than *T. costellatum*. *Tropidelasma pygmaeum* (Girty) is much smaller and more distantly costellate.

DISCUSSION.—This species is known only from 14 specimens, but, although they vary among themselves, the amount of variation is less than that seen in other species of like size. For thick-shelled forms, the notch on each side of the teeth and just under the palintrope is poorly developed compared to some other species.

*Tropidelasma furcillatum*, new species

PLATE 53: FIGURES 1-11

Conical, medium, rectimarginate to broadly and shallowly sulcate; outline transversely subelliptical

to subquadrate; costellae and growth laminae moderately strong. Pedicle beak blunt to elongate, commonly twisted or bent; interarea flat, bisected by pseudodeltidium with comparatively wide monticulus and low lateral ridges marking traces of growth of hinge teeth. Brachial valve moderately to strongly convex, with overhanging umbo and/or very low interarea and chilidium; hinge slightly narrower than maximum width of shell.

Pedicle valve interior with moderately strong hinge teeth protruding from underside of interarea, continuing posteriorly as convergent dental ridges along sides of arch of pseudodeltidium; hinge straight, with shallow groove extending laterally from distal side of each tooth to posterolateral corners of valve; muscle marks obscure, muscle possibly occupying shallow depressions in floor of valve.

Brachial valve interior wide with short to moderately long cardinal process notched at end by short Y-shaped incision, dividing process into 2 short longitudinally split prongs, with serrations along sides of each slit. Dentifers fused to underside of cardinal process supported by adventitious shell. Muscle area faintly defined, bisected by low median ridge; muscle marks faint. Margin of valve radially serrate.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 732           |                            |                             |                  |                |                     |           |
| 147881a            | 16.7                       | ?                           | 16.4?            | 11.0           | 6.4                 | 7.0       |
| 147881b            | ?                          | 16.9                        | 19.6             | 13.3           | ?                   | 8.5       |
| 153561a (holotype) | 17.3                       | ?                           | 15.7             | 11.2           | 6.7                 | ?         |
| 153561b            | ?                          | 16.4                        | 19.6             | 12.6           | ?                   | 7.0+      |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 512, USNM 728, 732.

DIAGNOSIS.—*Tropidelasma* of medium size with shallow notch in cardinal process.

TYPES.—Holotype: USNM 153561a; figured paratype: 153561b; measured paratypes: 147881a, b, 153561b.

COMPARISON.—*Tropidelasma furcillatum* is distinguished from other species of the genus by its shallowly notched, rather than deeply bifurcate, cardinal process, its bladelike dentifers, and by the presence in some individuals of a low brachial

interarea. It differs from species of *Diplanus* by its pseudodeltidium with low monticulus and lateral ridges that mark the paths of growth of the hinge teeth, by the comparatively weak hinge teeth, poorly developed or absent brachial interarea, unpitted brachial umbo, unthickened internal lateral walls of the pedicle interarea, and especially by the weaker costellation and less prominent growth laminae. The average size of *T. furcillatum* is that of a large specimen of any species of *Diplanus*, and the maximum size is larger than the largest known specimens of *Diplanus*. Therefore, despite the few

ambiguous features of this species, it clearly belongs with *Tropidelasma*, rather than with *Diplanus*.

DISCUSSION.—*Tropidelasma furcillatum* has features that would appear to link it to some branch of the *Diplanus* group; however, this species occurs high in the stratigraphic section, well above the highest known occurrence of *Diplanus*, and so it cannot be a truly intermediate form. Probably it represents a convergence by the *Tropidelasma* stock toward a *Diplanus* morphological type that it does not reach in this species.

*Tropidelasma gregarium* (Girty)

PLATE 61: FIGURES 1–37; PLATE 89: FIGURES 5–10;  
PLATE 745: FIGURE 69

*Streptorhynchus gregarium* Girty 1909:177, pl. 11: figs. 3–7.

Small for genus, variable in shape and outline; pedicle valve an elongate, often misshapen cone

with gently convex to somewhat flattened lateral profile. Interarea forming elongated triangle with narrow hinge as bases, apex making acute angle. Pseudodeltidium narrow, not well defined. Both valves costellate, costellae numbering 22 in 5 mm at anterior margin of lectotype.

Brachial valve elliptical to subcircular, maximum width at about midvalve; hinge narrower than midwidth; sides broadly to narrowly rounded. Greatest convexity near midvalve; umbonal region moderately convex; anterior slope steep. Anterior commissure irregular.

Pedicle valve interior with elongate teeth and stout dental ridges, musculature not impressed. Brachial valve interior with long shafted cardinal process having narrow prongs distally; dentifers low ridges welded to cardinal process shaft, but usually obscured by adventitious shell laid down on lateral and anterior surfaces. Median septum high, thin, serrate, dividing circular adductor field.

MEASUREMENTS (in mm).—

|                     | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|---------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USGS 2926           |                            |                             |                  |                |                     |           |
| 118494d (lectotype) | 14.4                       | 11.8                        | 15.4             | 8.5            | 7.0                 | 14.1      |
| 118494a             | 15.6                       | 12.4                        | 13.6             | 9.4            | ?                   | 13.0?     |
| 118494e             | 9.7                        | 7.6                         | 6.2              | 6.0            | 3.6                 | 7.8       |

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler thru Lamar members), Capitan Formation.

LOCALITIES.—Hegler: USNM 732a; Pinery: AMNH 435, 537, USMN 733, 736; Rader: AMNH 397, 410, USNM 725f, 725g, 740a; Lamar: AMNH L-2, L-3, L-6, 25, 37, 38, 39, 40, 347, 430, 528, USNM 725e, 728i, 728p, 728q, 738, 738b; Capitan: USGS 2926, USNM 740n, 750.

DIAGNOSIS.—Small *Tropidelasma* with erismata partially concealed and strong median septum in the brachial valve.

TYPES.—Lectotype: USNM 118494d; paratypes: 118494a–c, e, 155106; figured hypotypes: 152591a, d, e, l, n–q, 153545a, b.

COMPARISON.—The interior details of the cardinalia distinguish this species. It suggests *T. curtum* but it has a longer interarea on the pedicle valve, and the dorsal median septum is higher and longer. It differs from *T. furcillatum* in the presence of

the strong dorsal septum. It is much smaller than other described species.

DISCUSSION.—The type lot of this species consists of five specimens, all of them with both valves in contact, all exfoliated and generally damaged. As usual with this genus, no two of them are alike. These factors all combine to make the selection of a type specimen and identification with our silicified material very difficult. Specimen 118494e is immature and specimens 118494a and c are too badly damaged, both having incomplete pedicle valves. Specimen 118494b differs from the rest in having a fairly narrowly elliptical brachial valve and a longer interarea than the others. These features are probably a result of crowded growth, as Girty (1909:11) speaks of his type lot as having been found in a crowded condition. Specimen 118494d is thus left as the choice for a lectotype, and we chose this specimen, although it too is imperfect. Part of its right side is missing when viewed from the dorsal side, but the preserved half shows little

deformation and the brachial valve is fairly well preserved. Small patches of shell bearing the ornament are preserved on the pedicle valve.

Although the sockets of this species are formed by the sloping face of the dentifer, they are closed by secondary shell laid down on their anterior and distal edges. This secondary shell forms a ridge parallel, or nearly so, with the posterior margin. In some specimens this forms a small trough and shelf anterior to the posterior margin. A small vertical ridge extending from the posterior margin to the secondary shelf bounds the outer side of the socket. A few specimens show ridgelike extensions anteroventrally from the cardinal process, suggesting buried erismata, but they are not universal and not present in the young.

The pedicle valve has a narrow slot bounded anteriorly by a shelf and parallel to the hinge margin. This slot evidently accommodates the dorsal shelf of the opposite valve.

*Tropidelasma perattenuatum* (Girty)

*Streptorhynchus perattenuatum* Girty, 1909:180, pl. 29: figs. 3-3c.

The specimen on which this species is based is under 5 mm in length and width. The fine costellae of the exterior are like those of *Tropidelasma*, but the pseudodeltidium is not differentiated into the usual parts seen in that genus. The specimen is obviously a young one. The young *Tropidelasma* usually have a uniformly swollen pseudodeltidium, but this develops the median keel (monticulus) as adulthood is reached. Girty's species is undoubtedly the young of a species whose adult characters are unknown.

STRATIGRAPHIC OCCURRENCE.—Delaware Mountain Formation.

LOCALITY.—USGS 2962.  
TYPES.—Holotype: USNM 118496.

*Tropidelasma pygmaeum* (Girty)

*Streptorhynchus pygmaeum* Girty, 1909:178, pl. 30: figs. 3-6.—R. E. King, 1931:49, pl. 4: figs. 25.  
*Streptorhynchus?* species *a* Girty, 1909:180, pl. 30: fig. 7.

Shell small, irregularly conical; rectimarginate; outline transversely subelliptical to subquadrate; ornamented by moderately strong costellae alternating with slightly weaker ones, producing fasciculate pattern, all crossed by weak lines of growth; hinge slightly narrower than maximum width.

Pedicle valve evenly expanding or flaring, beak commonly bent or twisted, irregularly indented by contact with substrate during growth; interarea flat, traversed by weak growth lines, bisected by convex, large pseudodeltidium with relatively wide median arch, and flattened sides.

Brachial valve moderately convex, umbo meeting pedicle interarea between 90 and 180 degrees.

Pedicle valve interior with radial striae becoming deeper toward margin; hinge teeth thick, projecting forward from underside of interarea, extending posteriorly as strong convergent ridges under arch of pseudodeltidium; muscle marks not visible. No thickening lateral to teeth under palintrope.

Brachial valve interior with weak radial striae becoming deeper toward margin; cardinal process long, stout, slightly notched at distal end, with dentifers fused to underside, extending forward for about one-third length of process and producing large sockets; lateral terminations of dentifers fused to posterior valve wall, forming inside edge of shallow groove parallel to hinge, just inside hinge margin; muscle area slightly depressed, bisected by low thick myophragm; muscle marks obscure.

MEASUREMENTS (in mm).—

|                     | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|---------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| 118495a (lectotype) | 3.6                        | ?                           | 4.5              | 3.5            | 2.8                 | 2.9       |
| 118495b             | ?                          | 4.7                         | 4.8              | 4.0            | ?                   | 1.9       |
| 118495c             | ?                          | 5.0                         | 5.6              | 3.0            | ?                   | 2.1       |
| 118495d             | ?                          | 4.5                         | 5.2              | 3.6            | ?                   | 1.6       |

STRATIGRAPHIC OCCURRENCE.—Uncertain (see discussion below).

LOCALITY.—USGS 3763 (green).

DIAGNOSIS.—Small, thick-shelled *Tropidelasma* with fairly strong costellae.



TYPE.—Lectotype: USNM 118495a; paratypes: 118495b–d.

COMPARISON.—*Tropidelasma pygmaeum* is characterized by its small size, comparatively strong costellation, and slightly notched cardinal process. Small individuals, similar in size to Girty's cotypes, are relatively uniform in shape. Larger specimens tend to be more distorted and variable. The gross shape of some of the larger specimens approaches that of *Diplanus*, from which they differ in their weaker ornamentation and lack of brachial interarea. This species is morphologically closest to *T. furcillatum*, new species, which occurs in the Guadalupian of West Texas. *Tropidelasma pygmaeum* differs in its slightly stronger costellation, less convex brachial valve, less prominent socket plates, and much smaller maximum size.

DISCUSSION.—Were it not for the fact that the valves of *T. pygmaeum* are unusually thick, it would be thought that these specimens represent an immature form; however, they appear to be mature and will have to be so regarded until others are found to disprove the point. The locality from which Girty's specimens came is not known. King furnished no information on this point, but he identified the species from the Leonard, Hess, and Word formations. We did not obtain any specimens that, in our opinion, are identifiable with this species.

We chose the pedicle valve (USNM 118495a) as lectotype because this is the only specimen in the lot that has definite generic characters.

### *Tropidelasma rhamphodes*, new species

PLATE 54: FIGURES 1–39; PLATE 55: FIGURES 1–14

Large, irregularly conical, evenly expanding, not flaring; rectimarginate to slightly sulcate; brachial

valve outline nearly circular to moderately transversely subelliptical or subquadrate; hinge narrower than widest part; costellation fine, crowded, costellae numbering 3–5 per mm on large specimens and 4 per mm at front of holotype. Growth lines strong, closely spaced on pedicle valve and near edges of brachial valve, producing rugose shell surface. Shell also marked by irregular concentric undulations.

Pedicle valve beak deeply conical, normally curved posteriorly, producing convex anterior profile, commonly twisted slightly to left or right; interarea long, usually posteriorly concave, bisected by flat pseudodeltidium with narrow monticulus scarcely higher than flanking traces of the dental ridges. Lateral profile usually fairly evenly convex.

Brachial valve moderately to strongly convex in lateral profile, greatest convexity at umbo. Anterior profile having posterior margin variable, nearly in plane of pedicle interarea, or strongly overhanging. Anterior of old shells with steep anterior slope.

Pedicle valve interior with hinge teeth protruding from underside of interarea, continuing posteriorly as strong convergent dental ridges along sides of pseudodeltidium; interior surface fairly smooth, irregularities reflecting exterior undulations; muscle marks not preserved; valve edge radially serrate.

Brachial valve interior with strong bifid cardinal process, each branch longitudinally slit, with serrations along edges of slits; dentifers narrowly divergent, fused to underside of process; erismata present, defining deep and sharply arched umbonal cavity containing faintly impressed muscle area and short low myophragm, sockets relatively shallow. Margins of valve radially serrate, weakly in juveniles, but strongly in medium to large adults, and with serrations bearing rows of sharp papillae.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 707a          |                            |                             |                  |                |                     |           |
| 147882a            | 42.4                       | 34.0                        | 38.4             | 7.3            | 24.5                | 40.7      |
| 147882b (holotype) | 35.4                       | 32.7                        | 34.4             | 22.4           | 33.5                | 48.6      |
| 147882c            | 25.4                       | 25.7                        | 30.6             | 31.0           | 38.0                | 48.8      |
| 147882d            | 30.3                       | 26.1                        | 29.6             | 25.0           | 23.0                | 35.1      |
| 147882e            | 36.0                       | 30.5                        | 29.7             | 22.5?          | 26.0                | 34.7      |
| 147882f            | 27.8                       | 22.8                        | 25.3             | 20.6           | 17.7                | 24.0      |
| 147882g            | 23.9                       | 20.0                        | 26.3             | 15.2           | 13.6                | 23.4      |
| 147882h            | 22.0                       | 19.0                        | 23.7             | 14.6           | 15.8                | 21.7      |
| 147882i            | 18.0                       | 18.4                        | 19.3             | 13.5           | 15.7                | 20.4      |
| 147882j            | 18.2                       | 14.8                        | 15.2             | 11.5           | 12.7                | 17.2      |
| 147882k            | 16.0                       | 14.8                        | 16.6             | 12.2           | 11.0                | 16.0      |
| 147882-l           | 13.2                       | 13.0                        | 13.8             | 8.8            | 6.8                 | 11.7      |
| 147882m            | 8.7                        | 8.5                         | 9.6              | 7.0            | 5.4                 | 7.8       |
| 147882n            | 6.1                        | 6.0                         | 7.0              | 5.2            | 4.3                 | 6.2       |
| 147882o            | 4.0                        | 3.6                         | 4.2              | 3.0            | 2.0                 | 3.0       |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member).

LOCALITIES.—USNM 707a, 707h, 707u, 707z, 708z, 712p, 714t, 714y, 715j, 715v.

DIAGNOSIS.—Large, moderately elongated *Tropidelasma* with moderately umbonate brachial valve and rounded outlines dorsally.

TYPES.—Holotype: USNM 147882b, 147809, 147902, 147882a, d, f, h, j, m, p, 153554a-e; unfigured paratypes: 147882c, e, g, i, l, n, o; measured paratypes: 147882a, c-o.

COMPARISON.—*Tropidelasma rhamphodes* is characterized by its deeply conical shape, nearly circular to roundly subelliptical outline, relatively convex brachial valve, straight to slightly flexed margin, papillate edge of brachial valve interior, especially by the rugose ornamentation produced by its prominent growth lamellae, and by the broadly convex anterior profile of the pedicle valve. This species is closest to *T. culmenatum* of the Wolfcampian (Neal Ranch Formation), and a few specimens closely approach the form of that species. The above characteristics, especially the crowded costellate ornament, straight anterior commissure, and convex anterior profile, distinguish them. *Tropidelasma anthicum* of the Word Formation is also rectimarginate, but its shallow flaring pedicle valve and nonpapillate inner margin of the brachial valve distinguish it from *T. rhamphodes*. The greatly elongate pedicle valve and usually more slender form distinguish this species

from *T. strobilum*, new species, of the Lenox Hills Formation.

DISCUSSION.—Variation in *Tropidelasma rhamphodes* is typical for a species that lived attached. The pedicle valve may be deep or shallow, and it may be twisted or indented by irregularities in the object to which it attached during growth or against which it impinged. The brachial valve is moderately to strongly convex, and a few specimens in which the margin is slightly folded may be slightly concave near the anterior edge. A few specimens have flaring pedicle valves that produce a straight or even concave anterior profile that resembles *T. culmenatum*. No single diagnostic feature distinguishes *T. rhamphodes* from all other species, but the combination of characters is quite distinctive and the species is easy to recognize.

Specimens in the USNM collections are preserved as calcitic or siliceous replacements. Silicification is not normally complete; consequently, shells that appear in the acid residues are fragile and do not show fine details of the interiors, such as muscle marks. Ornamentation on the outside may be partly obscured on some specimens, but normally the external detail is better preserved by the silicification than is the internal. Somewhat more than half of the specimens are preserved as calcareous steinkerns or calcareous replacements filled with calcite. These can be identified by their characteristic shape and ornamentation. The calcareous specimens make

possible direct comparison with specimens of other species that are similarly preserved.

This species is anomalous in having what appear to be well-defined erismata extending from the anterior margin of the dentifers anterolaterally around the posterior of the muscle area. These are not buried in adventitious shell but stand out boldly. The few specimens preserving the brachial valve interior all show the same character. This is a departure from the majority of the species of *Tropidelasma* in which this character appears spasmodically or ambiguously.

### *Tropidelasma robertsi*, new species

PLATE 56: FIGURES 1-27

Large, pyramidal brachial valve strongly convex, pedicle valve elongated, sides narrowly rounded, anterior margin very broadly rounded. Anterior commissure often twisted but without definite fold

toward either valve. Hinge narrower than maximum shell width. Surface finely costellate, about 3 per mm at anterior margin.

Pedicle valve greatly elongated: hinge width about 0.7 midwidth; interarea usually flat or somewhat undulated; pseudodeltidium flat but marked medially by narrow monticulus extending full length of valve; ventral valve profile elongate, triangular, apex usually narrow, varying from 65° to 90°. Median region somewhat swollen, anterior of large adults flattened or depressed.

Brachial valve fairly strongly convex in lateral profile, broadly convex in anterior profile, sides somewhat flattened. Umbonal region swollen; beak inconspicuous. Slopes to cardinal extremities moderately steep.

Pedicle valve interior with thickened dental ridges and small, sharp teeth; other details obscure. Brachial valve interior with long, slender cardinal process having short erismata. Other details obscure.

#### MEASUREMENTS (in mm).—

|                    | <i>pedicle</i><br><i>valve</i><br><i>length</i> | <i>brachial</i><br><i>valve</i><br><i>length</i> | <i>hinge</i><br><i>width</i> | <i>midwidth</i> | <i>thickness</i> |
|--------------------|---|--|------------------------------|-----------------|------------------|
| 153558c            | 18.2  | 16.5   | 12.6                         | 20.0            | 17.2             |
| 153558d            | 30.3  | 30.3   | 25.6                         | 33.7            | 29.8             |
| 153558h            | 30.0  | 23.4   | 25.0                         | 29.0            | 31.2             |
| 153558g (holotype) | 55.7  | 37.3   | 39.0                         | 57.4            | 56.2             |
| 153558i            | ?   | 47.5   | 53.7                         | 67.6            | ?                |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Sullivan Peak Member).

LOCALITY.—USNM 733j.

DIAGNOSIS.—Large *Tropidelasma* with wide, strongly convex brachial valve.

TYPES.—Holotype: USNM 153558g; figured paratypes: 153558a-f, h; measured paratypes: 153558c, d, h, i.

COMPARISON.—This is the largest named *Tropidelasma* in the Glass Mountains. In addition to size, it differs from *T. culmenatum* in having a twisted anterior commissure, whereas that of the Neal Ranch species is strongly sulcate. It is also less swollen medially, and the brachial valve is more convex than that of *T. culmenatum* and has well-defined erismata. *Tropidelasma rhamphodes* is a smaller, more chunky species with a nearly circular, moderately convex brachial valve, a sulcate anterior commissure and rounded outlines.

DISCUSSION.—*Tropidelasma robertsi* was taken

from the *Coscinophora* bioherm at USNM 733j, where it was so intimately cemented among the *Coscinophora* that it proved difficult to obtain good specimens for description. Also, most of the specimens are riddled by borings. This species is named for John Roberts, University of New South Wales, Australia, who collected with us in 1968.

### *Tropidelasma strobilum*, new species

PLATE 57: FIGURES 1-20

Shell irregularly conical, usually long and narrow, rarely wide and abruptly tapered; outline subcircular to transversely subelliptical; hinge narrower than widest part; costellae moderately strong, closely crowded, numbering 5 per mm, 3 large and 2 small, growth lines weak. Pedicle valve bent or twisted in any direction; interarea long, bisected by pseudodeltidium with narrow monticulus and

lower lateral ridges marking traces of dental ridges. Brachial valve moderately to strongly convex, bumpy and irregular, umbo overhanging hinge. Pedicle valve interior with strong hinge teeth and thick dental ridges; muscle marks not seen. Brachial valve interior with long bifurcated cardinal

process supported by cuplike plates fused to underside and arching over umbonal cavity, lateral extremities defining limits of slightly depressed muscle area with low myophragm; hinge sockets on each side of process round, deep; margins of valve finely serrate radially.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 705k          |                            |                             |                  |                |                     |           |
| 147780a            | 46.3                       | 30.9                        | 38.5             | 25.0?          | 45.2                | 46.4      |
| 147780b (holotype) | 36.4                       | 29.3                        | 36.7             | 20.0?          | 33.4                | 44.8      |
| 147780c            | 39.6?                      | 20.5                        | 26.0             | 18.9           | 49.0                | 58.6      |
| 147780d            | 21.7                       | 20.4                        | 23.4             | ?              | 29.6                | 41.0      |
| 147780f            | 20.5                       | 20.5                        | 27.0             | 19.0           | 19.6                | 25.6      |
| 147780g            | 19.6                       | 17.6                        | 18.5             | 12.4           | 16.5                | 24.0      |
| 147780h            | 15.0                       | 15.0                        | 16.6             | 10.7           | 5.8                 | 8.7       |
| 147780i            | 14.4                       | 8.9                         | 10.7             | 6.7?           | 11.5                | 20.0      |
| 147780j            | 16.9                       | 10.9                        | 12.4             | 8.8            | 10.5                | 14.5      |

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation (*Scacchinella* bed).

LOCALITIES.—USNM 705, 705k, 705m, 705q, 705s, 707j, 707u, 709w, 715.

DIAGNOSIS.—Large, usually greatly elongated *Tropidelasma* with strongly umbonate brachial valve.

TYPES.—Holotype: USNM 147780b; figured paratypes: 147780a, c, g, 147793; Unfigured paratype: 147780d–f, h–j; measured paratypes: 147780a, c–j.

COMPARISON.—*Tropidelasma strobilum* is characterized by its elongate and twisted pedicle beak, large size, bumpy, irregular surface with fine costellation, weak circum-umbonal growth lines. It most closely resembles *T. rhamphodes* from which it is distinguished by its more irregular growth, longer pedicle valves, more frequent twisting and bending (especially anterior curvature of the beak, making the pedicle interarea convex), and much weaker lines of growth. *Tropidelasma strobilum* differs from *T. culmentum* by its nongeniculated anterior and lack of a ridged anterior slope of the pedicle valve, as well as a more convex brachial valve, narrower hinge, and generally more irregular and distorted shell. It differs from *T. pygmaeum* (Girty) by its much greater maximum size and relatively weaker ornamentation, and from *Chelononia straminea* by its high conical shape, unflared hinge and interarea, and much weaker costellation. Its normally longer and narrower pedicle valve, more ir-

regular shape and larger maximum size distinguish it from *T. anthicum* of the Word Formation.

DISCUSSION.—*Tropidelasma strobilum* is the most variable species of the genus in the Glass Mountains. It is characteristically bent or twisted, and ranges from very long and nail-shaped to low and abruptly tapered. All specimens of this species are preserved as calcite replacements or internal molds; none is silicified. This makes it difficult to compare with some of the species that are preserved only as siliceous replacements; however, the species that is closest to *T. strobilum* is *T. rhamphodes*, new species, of which many specimens are preserved as calcareous replacements, although most are silicified.

Several specimens are broken in such a way that the cardinal process, hinge teeth, and brachial muscle area are exposed. These features are characteristic for the genus, but none is peculiar to the species.

*Tropidelasma undulatum* (R. E. King)

PLATE 108: FIGURES 1–5

*Streptorhynchus undulatum* R. E. King, 1931:51, pl. 4: figs. 11a–d (probably not figs. 12 and 13) [= *Tropidelasma rhamphodes* Cooper and Grant].

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (low).

LOCALITY.—R. E. King 211.

**TYPES.**—Lectotype: YPM 11406.

**DISCUSSION.**—Two of the specimens figured by King (1931, pl. 4: figs. 12, 13) are exfoliated individuals and not helpful in obtaining a good idea of this species. The holotype is a badly damaged silicified specimen with both sides missing and the middle part exfoliated. It preserves enough of the exterior to show the fine crowded costellae, and the interarea and beak are well displayed. The character of the pseudodeltidium with its flattened sides and narrow monticulus is characteristic of *Tropidelasma*. The beak is too mineralized to indicate the presence or absence of septa. In spite of this the specimen is best assigned to *Tropidelasma* because the pseudodeltidium is tropidelasmoid rather than like that of *Derbyia*. No radial costae prevent relationship to *Meekella*, whose pseudodeltidium is like that of *Tropidelasma*. King's type specimen is thus probably correctly assigned to *Tropidelasma*, but identification of its specific characters is more difficult.

*Tropidelasma* is common in the Decie Ranch Member of the Lenox Hills, but the specimens do not appear to accord with the specific characters determinable from King's holotype of *S. undulatum*. Specimens described herein as *T. rhamphodes* occur abundantly at the west end of the Lenox Hills, but they are generally more elongated, have a more convex adult brachial valve, are narrower, and are not so strongly wrinkled. We are unable to identify these specimens with King's species.

King reports his species from his locality 17 at the east end of the Lenox Hills. This collecting place appears to be in the Sullivan Peak Member, rather than in the *Scacchinella* beds of the Decie Ranch Member. Other localities (105, 211) listed by King are in the *Scacchinella* beds of the lower Skinner Ranch Formation (= Decie Ranch Member) on the northwest side of the Hess Ranch Horst. The horizon of King's locality T9 is uncertain. It is possible that King's type specimen was derived from a different biohermal assemblage, and is thus specifically different from the species of this genus west of it. It appears to be a fact that a great part of the speciation in the Glass Mountains took place on, or in the vicinity of, bioherms. We therefore recognize King's species as separate from those described herein, but we were unable to find additional specimens.

*Tropidelasma undulatum* has a more strongly elevated and wider fold on the pseudodeltidium than *T. rhamphodes*, is thinner-shelled, and has a less convex and less even brachial valve.

### *Tropidelasma* species 1

Fairly large, pedicle valve elongated, interarea broad and flattened, pseudodeltidium depressed. Lateral profile of pedicle valve convex near mid-valve, narrowly domed in anterior profile, sides nearly straight. Anterior commissure strongly sulcate. Hinge almost equal to midwidth. Brachial valve flatly convex, fairly strongly sulcate anteriorly. Surface marked by numerous crowded, fine costellae about 4 per mm at front. Cardinal process very long and prominently forked.

**MEASUREMENTS** (in mm).—Pedicle valve length 21.4, brachial valve length 15.5, maximum width 18.2, hinge width 15.3, interarea length 13.0, thickness 17.0.

**STRATIGRAPHIC OCCURRENCE.**—Skinner Ranch Formation (Sullivan Peak Member).

**LOCALITY.**—USNM 714y, 723-1.

**TYPES.**—Described specimens: USNM 147850a-e; 152600a=1. → see T. sp 3

**DISCUSSION.**—This species is known only from a few fragmentary specimens, but it clearly is unlike any other in the Glass Mountains. The closely crowded costellae of the exterior and the somewhat geniculated lateral profile of the pedicle valve are distinctive. Although *Tropidelasma* is common in the *Scacchinella* beds of the Decie Ranch Member, it has been found in a few places in the Sullivan Peak Member, the fauna of which is similar to that of the Decie Ranch Member.

### *Tropidelasma* species 2

PLATE 57: FIGURES 21, 22

Unusually large, wide, ornament delicate, costellae of several sizes, unevenly alternating. About 5 costellae per mm at midlength, 3 costellae of first magnitude, alternating with ones of secondary size. Figured specimen about 48 mm long, 56 mm wide, interarea approximately 25 mm long and estimated 30 mm wide. Pseudodeltidium broad, flat, about 13 mm long at anterior end. Lateral profile flatly convex bulging near anterior.



STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITY.—USNM 702q.

TYPES.—Described and figured specimen: USNM 147888.

DISCUSSION.—This is another of the peculiar species having strong Permian aspect and affinities that occur in the *Uddenites*-bearing Shale Member. The Pennsylvanian elsewhere in North America has not produced any streptorhynchids of large size or Permian aspect. The specimen described above is undoubtedly a new species as it is larger than any other species described from the Glass Mountains, is differently ornamented and differently shaped. Unfortunately, it is represented by a single pedicle valve.

### *Tropidelasma* species 3

PLATE 101: FIGURES 15–19

Species about medium size, indicated by 15 specimens of rather poor preservation. Pedicle valve conical, interarea fairly short, apsacline; valve fairly deep, long side moderately convex in profile. Brachial valve very strongly swollen, with long cardinal process.

MEASUREMENTS (in mm).—USNM 152602: pedicle valve length 20.3, brachial valve length 16.3, maximum width 19.0, hinge width 11.6, interarea length 8.0, thickness 15.8.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (top).

LOCALITIES.—USNM 723–1, 714y, ?727a.

TYPES.—Figured specimens: USNM 152600a, ~~b~~.

DISCUSSION.—This is almost certainly an undescribed form as shown by the great inflation of the brachial valve. The ornament is too poorly preserved to define. Specimens from USNM 727a are much misshapen and may or may not belong here. More specimens are needed from both localities.

### *Tropidelasma* species 4

PLATE 30: FIGURES 7–10; PLATE 61: FIGURES 38–43;

PLATE 124: FIGURES 11–13

Mostly immature specimens and one large adult brachial valve suggest a species similar to *T. rhamphodes* having a flaring and sulcate anterior. Large brachial valve elongate elliptical, with long cardinal

process but well-defined erismata in some specimens. Exterior sulcate anteriorly, with costellae somewhat bundled but obscure. Outer margin flattened on inside.

MEASUREMENTS (in mm).—Pedicle valve (USNM 152601a): length 14.2, brachial valve length?, maximum width 12.6, hinge width 8.0, interarea length 7.6, thickness 8.4?; brachial valve (USNM 152601b): length 20.2, maximum width 21.4, hinge width 15.4, thickness 5.5.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (lower).

LOCALITY.—USNM 721u.

TYPES.—Figured specimens: USNM 152601a, b, 152603a, b, 153829.

DISCUSSION.—This species suggests *T. rhamphodes*, but it differs in being attenuated anteriorly, more narrowly hinged, and having maximum width near midvalve.

### *Tropidelasma* species 5

A single specimen represents a fifth undescribed species of *Tropidelasma*. This one has well-differentiated costellae, strong alternating with weaker, very strongly umbonate, and anteriorly spreading brachial valve and narrowly conical pedicle valve. The pseudodeltidium is flat, but it is marked medially by a monticulus.

MEASUREMENTS (in mm).—Pedicle valve length 10.0?, brachial valve length 11.4, maximum width 13.2, hinge width 8.0?, interarea length 6.0?, thickness 7.7?.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (top).

LOCALITY.—USNM 705r.

TYPES.—Described specimen: USNM 152602.

DISCUSSION.—This may be an immature form related to *Tropidelasma* species 3.

### Family MEEKELLIDAE Stehli, 1954

Costellate to costate Derbyiaceae having separate, well-developed dental plates or spondylium in pedicle valve and strongly developed cardinal process in brachial valve.

The three genera from West Texas in this family are generally much alike in external appearance, but they are most closely related by high specialization of the cardinal process. This structure is

greatly elongated and has a platform of considerable size, the promontorium, developed in connection with the socket.

Genera found in the Glass Mountains are: *Meekella* White and St. John, 1867; *Niviconia*, new genus; and *Geyerella* Schellwien, 1900a.

### Genus *Meekella* White and St. John, 1867

*Meekella* White and St. John, 1867:120.—Hall and Clarke, 1892:264; 1894:155.—Girty, 1909:205.—R. E. King, 1931:52.—Dunbar and Condra, 1932:124.—Sokolskaya, 1954:152.—Stehli, 1954:303.—Williams, et al., 1965:H405.

Conical, costate to plicate, with lidlike brachial valve (specimen lived attached by pedicle valve apical region); dental plates present, separate on floor of pedicle valve or fused at point of contact along floor to form pseudospondylium; cardinal process long, curved, distally bifurcate, with dentifers fused to shaft with fossettes for dental ridges and teeth; and forming promontorium; erismata divergent, extending into umbonal arch of brachial valve, and delimiting posterior part of flabelliform muscle area.

TYPE-SPECIES.—*Plicatula striato-costata* Cox (1857:568, pl. 8: fig. 7).

DISCUSSION.—*Meekella* has been known for a long time and its external details are familiar to all students of late Paleozoic fossils. Its interior, however, is much less well known except for generalities. The reason for lack of knowledge is the difficulty of obtaining good interiors. *Meekella* is fairly well articulated, so separated valves are not easy to obtain. Where they are common, as in the Bone Spring Formation, it would be almost impossible to obtain a free cardinal process were it not for silicification. This is true also of other details of the interior, which have hitherto been unknown or not clearly seen. The Glass Mountains and Sierra Diablo specimens, thus, offer a great opportunity to understand this interesting genus. The Capitan Limestone and its equivalents in the Guadalupe Mountains have thus far not yielded many specimens of *Meekella*, silicified or otherwise.

Information on the dental plates and muscle marks of the pedicle valve has been obtained from many of the silicified specimens. The dental plates in various species usually have a different lateral profile or anterior edge. Those that are herein

termed receding usually have the plate extending as a dental ridge under the palintrope edge for some distance ventrally before it expands into a full plate and extends to the floor. In others this distal narrowness extends for only a short distance, and in still others not at all. The receding plate lateral profile shows a deep notch in the dental plate.

The dental plates meet the valve floor at varying distance from each other. In some specimens they are so close, they nearly touch. In these, a union between the two may be achieved by deposition of callus between the plates on the floor of the valve. This structure may be described as a pseudospondylium. This condition is not uniform in any species, but it is more frequent in some than in others. In many specimens the dental plates extend almost vertically to the floor and maintain a fair distance from each other at the floor. It is more usual, however, for the dental plates to converge but not to meet. In many species their anterior ends are extended anteriorly along the floor.

It has been generally believed that the dental plates bounded the area for muscle attachment, but evidence revealed by some large specimens from the Glass Mountains shows that this may not be correct. These specimens of *M. enormis*, new species, have a large and elevated muscle field anterior to, and surrounding, the distal extremity of the dental plates. These scars were seen only in old and very large specimens. They are not seen in most specimens because of the usual thin shell and lack of old-age thickening. The strong costation or plication of the exterior is not materially changed within the muscle field, which is revealed by the strongly thickened and elevated anterior rim. Although the muscle field was revealed in only two specimens, it must have existed in all the others, and *Meekella* anatomy has been misinterpreted. This new information suggests that the dental plates of *Meekella* are in reality equivalent to the median septum of *Derbyia*, which is surrounded by a large and flabellate muscle scar like that of *Meekella*.

The pseudodeltidium of *Meekella* is like that of *Tropidelasma* in the Derbyiacea and of *Triplexia* in the Triplexiacea. It is flat between the dental plates and teeth, a phenomenon that defines the delthyrium, but especially in old specimens the pseudodeltidium is often outlined by narrow de-

pressions that run from just inside the teeth to the apex. The *Meekella* pseudodeltidium is also marked by a narrow, elevated ridge or fold, termed the "monticulus," along the middle from the anterior edge to the apex. This narrow fold is formed by the chilidial boss, which is inserted into its anterior opening. The notch produced by the open end of the monticulus is bounded on each side by a lobe of the pseudodeltidium that produces two small scooped-out hollows, where these lobes moved in the opening and closing of the valves. The monticulus is often mistaken for the pseudodeltidium, but actually it is only a part of it (Sokol'skaya, 1954:59, fig. 59).

The cardinal process of the brachial valve is the most distinctive structure of the genus. It is like that of several other genera, but it is displayed to perfection in some species of *Meekella*. The length of the cardinal process generally is closely correlated with the length of the interarea of the pedicle valve. Species with long interareas generally have a long cardinal process, whereas its length is retarded in the species with wide and short interareas.

The following analysis of the meekellid cardinal process is based partly on beautifully preserved specimens of *Niviconia globosa* (King), in which all features are similar to *Meekella* but exaggerated so that the component parts are easily seen (Figure 40). The cardinal process consists of several elements welded together to form a long curved plate, U-shaped in cross-section and with the open

part of the U facing anteriorly. The upper, solid rounded base of the U is termed the "shaft" and may be compared with this part of the cardinal process in other genera having an elongated cardinal process, such as *Triplesia*. The shaft forks distally and each prong of the fork is slit longitudinally for nearly its full length on the posterior side, but on the anterior edge or side the slit is short and divides each extremity into two small lobes. Widening of these slits at the distal end may produce a quadrilobed cardinal process in large or old specimens. The longitudinally slit tines of the fork are the myophore of the cardinal process. The inner margins of the slits are serrated and show evidence of muscular attachment.

The proximal end of the upper surface of the shaft at its junction with the beak has a thick triangular boss, herein designated the "chilidial boss," which is in the position of the chilidium and is thought to represent a modification of that structure. This boss fills the median notch of the narrow ridge or monticulus that extends longitudinally for the length of the pseudodeltidium of the pedicle valve. On each side of the chilidial boss are two small depressions that mark the path of the proximal distal lobes of the pseudodeltidium, which lie on each side of the notch at the butt of the monticulus. In some species a conspicuous keel or axial ridge extends along the crest of the shaft to about the position of the base of the forked myophore.

On the anterior side of the shaft a flat or concave

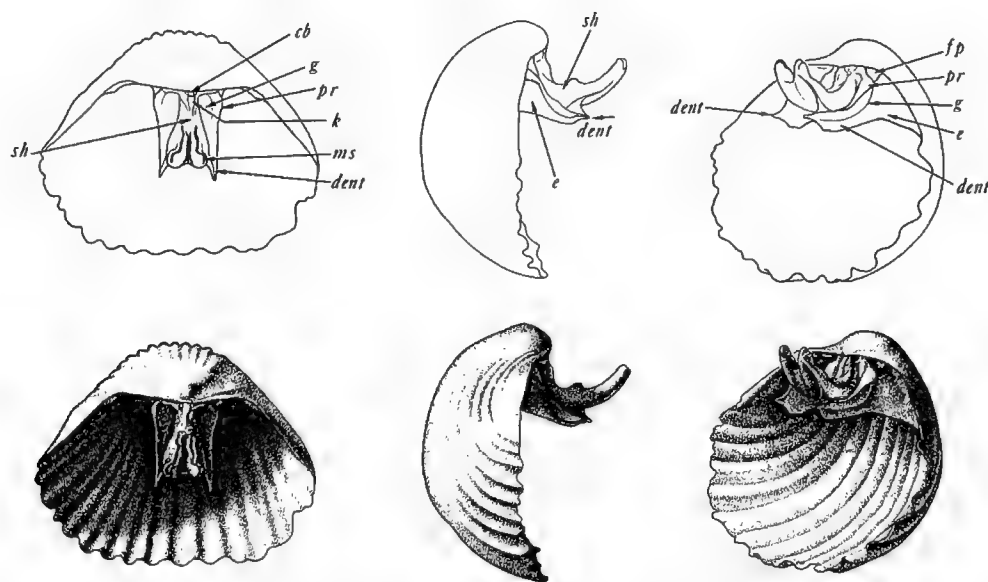


FIGURE 40.—*Niviconia globosa* (R. E. King): Dorsal valve, showing cardinal process and its parts (*cb*=chilidial boss, *dent*=dentifer, *e*=erisma, *fp*=fulcral plate, *g*=gusset, *k*=keel, *ms*=myophore slit, *pr*=promontorium, *sh*=shaft).

plate unites the shaft with the dentifer. The edge of the dentifer is sharp and thin, extending distally into a blunt, free point, which extends beyond the ends of the forked myophore. In a proximal direction the dentifer passes into the widely flaring erismata, supporting plates or broad struts that buttress the shaft of the cardinal process and tie it to the wall of the valve. The plate uniting the dentifer to the cardinal process shaft is herein termed the "gusset." This plate is variable in width and direction, but unusually large and steeply inclined in *Niviconia globosa*, but in some species of *Meekella* it flares laterally to produce a more expanded cardinal process.

Outside of the gusset and buttressing the brachio-phore is another winglike plate, herein termed the "promontorium," that terminates proximally in a sharp bend and thickened ridge bounding the inside wall of the socket (toward the brachiopod's body). This seems to have the same function as the socket ridge of rhynchonellids. The promontorium is termed such because it looks out over the shell cavity and forms the lateral high point on the cardinal process. This plate, which is variously developed among *Meekella* species but most strongly formed in *Niviconia globosa*, is a buttress for the socket and for the dentifer as well. Its edge curves from the socket anteroventrally to form a strengthening ridge on the outside of the dentifer. In *N. globosa* the promontorium and the gusset define a deep cup on each side of the shaft, but this is the only species in which they are so concave and strongly pronounced (Figure 40).

The sockets of *Meekella* are defined by well-formed fulcral plates that appear at the angle of the promontorium, where it forms a ridge on the side of the socket. The fulcral plate is variable, but it appears to be a definite plate, not merely an excavation in the shell tissue.

The growth of the promontorium can be traced from the ridgelike dentifer in immature specimens to the complex adult structure. It forms by the widening and deepening of the gusset and the lateral expanding of the dentifer. The promontorium is thus an expanded dentifer plus the gusset. The fulcral plate is variable, but it appears to be a definite plate, not merely an excavation in the shell tissue.

Species of *Meekella* from the Glass Mountains

are highly variable. Each species has a characteristic aspect that is apparent when a large sample is viewed in the aggregate. Unless a single isolated specimen is very near the norm for its species it may be impossible to identify. No single simple character suffices to distinguish species of *Meekella* from one another; moreover, not all specific characters are such that they can be observed on each specimen; for instance, maximum size, average size, range of variation in certain characters like plications and dental plates, and changes that take place with growth are important specific characters in this genus.

The necessity of having a group of specimens for specific identification makes it difficult to establish with certainty the identity of most earlier named species. All of Girty's (1909) species are based on fragmentary, immature, or otherwise scanty material, some of which have inaccurate locality data. One of these species, *Meekella attenuata* Girty, has come to have a certain meaning through the work of Stehli (1954) despite the inadequacy of the holotype and paratypes. Apparently the holotype was collected in the Sierra Diablo, although some doubt about this exists (Girty, 1909:512, USGS 3764). Young of the species that Stehli called *M. attenuata* Girty actually appear conspecific with the holotype. We have not been able, however, to recognize *M. attenuata* in the Glass Mountains.

King (1931) used the name "*M. attenuata* Girty" for some of his specimens from the Glass Mountains. His description of that species, especially of the exceptionally fine-ribbed specimens that he mentions, seems to fit our *M. caperata*, new species, although most of his illustrations (pl. 5: figs. 2, 4, 5, 7) are of specimens of *M. skenoides* Girty, and one (fig. 4) shows *M. calathica*, new species. We agree with R. E. King's (1931:54) suggestion that *M. multilirata* Girty is based on characters that are highly variable and are not reliable for distinction of species. The name "*M. multilirata*" should be confined to its holotype.

R. E. King (1931:55) recognized *Meekella mexicana* Girty in the Glass Mountains, but large collections from the Wolfcamp Formation have produced a series of specimens with features transitional from those he identified as *M. mexicana* Girty to those that he called *M. irregularis texana*



King (now called *M. texana* King). Since Girty's holotype and paratype specimens of *M. mexicana* differ in several features from King's "*M. mexicana* Girty," we have used King's name instead of the doubtfully applicable name "*M. mexicana*."

Species of *Meekella* in the Glass Mountains all differ from European and Asian species of the genus. None is as weakly plicate and strongly costellate as *M. ufensis* Tschernyschew (1902:587) or *M. baschkirica* Tschernyschew (1902:586), except juveniles of *M. texana* R. E. King. *Meekella eximia* (Eichwald) (Tschernyschew, 1902:582) resembles *M. prionota*, new species, but it is more weakly plicate and the pedicle valve is less convex. Judging from the variability of Texas species, however, we doubt that all three of these so-called "species" of Tschernyschew are more than variants within a normal population of a single species, especially because all were collected from a single zone, the *Productus cora* "horizon." These three species plus the specimens that he called *M. striatocostata* (Cox) have a narrower range of variation combined than does *M. texana* King or even the least variable of our Texas species, *M. prionota*. Probably *M. timanica* Tschernyschew (1902:585) is distinct from the others; it differs from all Texas species by its wide, low interarea and its very weak plication. No Texas species gets as large as *M. timanica* without becoming much more strongly plicated. *Meekella uralica* Tschernyschew (1902:583) resembles *M. texana* King in its gross external form, but it is much more weakly plicated for its size. Also, specimens of *M. texana* as large as Tschernyschew's illustrated specimens (pl. 51: figs. 1, 2) are much more deeply conical, and the interarea has curved to meet the plane of commissure at nearly a right angle instead of maintaining the large obtuse angle of *M. timanica* shown in figure 1b of plate 51 (Tschernyschew, 1902).

*Meekella multiplicata* Licharew (1932:24, 44) most nearly resembles *M. grandis* R. E. King (Licharew compared it to *M. occidentalis* Newberry, which we believe is the same as King's species). Its plications are much finer and more numerous, however, and, to judge from Licharew's illustrations (pl. 6: fig. 1b), the brachial valve is more strongly convex.

Huang (1933:27) described *Meekella kueichowensis* from the Permian of China. His figures (pl.

3: figs. 19, 20; pl. 4: figs. 1-4) show a large *Meekella* that is similar to *M. grandis* King (= *M. occidentalis* (Newberry)). *Meekella kueichowensis* is closer to *M. occidentalis* and differs from *M. grandis* in its smaller and more numerous plications, lower convexity, and less transverse outline. The interiors of *M. kueichowensis* and *M. occidentalis* are known only from internal molds.

Schellwien (1900a:19-24) described several species of *Meekella* from the Carnic Alps. Of these, *M. irregularis* Schellwien most nearly resembles a Texas species that R. E. King (1931:55) named as a new variety, *M. irregularis* var. *texana*, which we now consider to be specifically distinct. Some individuals of *M. texana* King closely resemble Schellwien's illustrations of *M. irregularis* (pl. 2: figs. 8, 9), but most of the population of *M. texana* is made up of individuals less transverse, more coarsely and irregularly plicate, with plications beginning farther forward of the beak. *Meekella evanescens* Schellwien is not similar to any of the Texas species, being weakly plicate, deeply conical, and with an auriculate hinge.

*Meekella depressa* Schellwien is small, scarcely plicate, and shallowly conical. Probably it represents a suite of juvenile shells from one or more of his other species. *Meekella procera* Schellwien closely resembles *M. irregularis* and differs from *M. texana* in most of the same respects. In addition, most specimens of *M. texana* that are as large as the illustrated specimen (pl. 3: figs. 1, 2) of *M. procera* have the interarea meeting the plane of commissure at nearly a right angle. In *M. procera* the beak is slanted strongly backward, and the interarea and plane of commissure intersect at a large obtuse angle.

### *Meekella angustiplicata*, new species

PLATE 102: FIGURES 1-39

Medium size for genus, pedicle valve moderately long, conical, brachial valve convex, dorsal view subcircular to slightly elliptical. Sides and anterior rounded; anterior commissure not regularly folded. Hinge narrow, slightly auriculate. Surface costellate and finely costate, costae narrowly rounded and closely crowded, increasing by bifurcation anterior to umbo, numbering 4 in 5 mm at front margin of adults. Umbonal region for about 10 mm anterior to beaks finely costellate.



Pedicle valve triangular in lateral profile, ventral side gently convex; anterior profile moderately domed. Interarea long, flat, or gently convex; anterior profile moderately domed. Interarea long, flat, or gently concave, nearly at right angle to lateral commissure. Pseudodeltidium flat, with monticulus. Beak ridges strong. Beak usually forming acute angle.

Brachial valve moderately convex in lateral profile, umbonal region swollen and convex; anterior profile fairly evenly and broadly convex. Umbonal

slopes somewhat swollen and steep. Anterior slope gentle.

Pedicle valve interior with small teeth, strongly receding dental plates converging toward floor but seldom uniting.

Brachial valve interior with long, proximally spreading cardinal process, deeply forked at distal end. Promontorium slightly protuberant. Erismata short and wide. Myophragm low in old specimens.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 725c          |                            |                             |                  |                |                     |           |
| 150886a            | 6.7                        | 5.9                         | 6.5              | 4.6            | 2.8                 | 3.5       |
| 150886b            | 7.6                        | 6.4                         | 8.0              | 5.6            | 3.4                 | 4.3       |
| 150886c            | 9.5                        | 9.5                         | 11.8             | 8.7            | 5.0?                | 8.0?      |
| 150886d            | 10.6                       | ?                           | 10.9             | 7.8            | 9.2                 | 7.5       |
| 150886e            | 17.4                       | 15.4                        | 18.5             | 12.0           | 8.9                 | 16.2      |
| 150886f            | 21.5                       | 18.0                        | 22.3             | 15.9           | 13.4                | 21.6      |
| 150886g (holotype) | 22.7                       | 20.6                        | 25.8             | 16.7           | 14.0                | 22.6      |
| 150886h            | 30.5                       | ?                           | 29.6             | 20.0*          | 13.0                | 14.0      |
| 150886i            | ?                          | 27.4                        | 30.0             | 19.3           | ?                   | 10.5      |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (100 and 120 feet above base).

LOCALITIES.—AMNH 696, 697, USNM 725c, 725s, 728t.

DIAGNOSIS.—Medium-sized *Meekella* with fine, closely crowded and numerous costae.

TYPES.—Holotype: USNM 150886g; figured paratypes: 150886b, e, j–q; measured paratypes: 150886a–i; unfigured paratypes: 150886a, c, d, f–i.

COMPARISON.—Only *Niviconia globosa* (R. E. King) and *M. caperata*, new species, need be compared with this species. The two share in common a similar profile and outline and more uniform costae than are usual in the genus. *Niviconia globosa* attains a much larger size than the Bone Spring species, is more coarsely costate, and the costae are angular, more elevated, and less numerous than those of *M. angustiplicata*. Moreover, the interiors of both valves of *M. angustiplicata* are less exaggerated than those of the Glass Mountains species. The cardinal process is not nearly so ponderous, erismata are shorter and more widely spread than in *N. globosa*. Dental plates of the Bone Spring species are more receding and much shorter than those of the Glass Mountains species.

*Meekella angustiplicata* resembles *M. caperata* in the number of costae, but it differs in having costae much more closely crowded together and the brachial valve is more transversely elliptical rather than subcircular in the Bone Spring species.

DISCUSSION.—Specimens of this species are difficult to obtain in uncrushed form or without siliceous fillings. Clean shells are rare, but, when obtained, they show their details with exceptional clarity.

*Meekella attenuata* Girty

PLATE 103: FIGURES 1–34; PLATE 104: FIGURES 11–20

*Meekella attenuata* Girty, 1909:205 (?), pl. 24: figs. 7–9a, pl. 25: figs. 4–4d.—R. E. King (part), 1931:52.—Stehli, 1954:304, pl. 18: figs. 6–11.

*Meekella hessensis* Stehli (not King), 1954:305, pl. 18: figs. 3–5.

Girty's holotype is a small and immature specimen, his paratypes are somewhat exfoliated specimens, less youthful than the holotype, but nevertheless young. The holotype is said to come from the Sierra Diablo, eight miles north of the Hazel Mine, Van Horn (30') Quadrangle, Texas. Para-

types are from the Bone Spring Limestone about two miles south of El Capitan. The holotype probably is from the lower Bone Spring, but the paratypes give no indication of the level from which they may have been taken, probably high in the Bone Spring. Stehli (1954:304) evidently regarded the paratypes as conspecific with the holotype, more representative of his large collection of *Meekella* from the lower Bone Spring Formation. We have compared the holotype with immature specimens from Stehli's localities in the national collection and find specimens that duplicate it in many details. Probably this is the stratigraphic level from which the type came. *Meekella attenuata* appears to be common at this level, and it may be obtained in abundance by dissolving lower Bone Spring Limestone. The specimens consist chiefly of separated valves, as noted by Stehli, but they are well preserved and show the anatomical details to perfection.

*Meekella attenuata* is about medium size, conical, subcircular (in dorsal view). The hinge is narrow, sides widen rapidly to midvalve and narrow to the broad anterior curve. The anterior commissure is rectimarginate. The costae are narrowly rounded,

direct, only rarely bifurcated; interspaces are narrower than the costae. The maximum number of costae is 22 in a large individual and about 15 in smaller ones. The posterior is costellate and non-plicate for 8 to 12 mm, the holotype being non-plicate for about 10.5 mm.

The pedicle valve is gently convex in lateral profile and broadly and gently convex in anterior profile. The interarea is narrow and short, the beak attenuated and somewhat abruptly curved. The interarea and commissure in most specimens are at an acute angle.

The brachial valve is moderately convex in lateral and anterior profiles about as deep as the opposite valve. The valve is full medially, but some anterior flattening occurs in some specimens.

The pedicle valve interior has strong dental plates and long, slender teeth, the former only slightly convergent and usually narrowly separated along the valve floor. The brachial valve has a moderately long cardinal process, slightly forked distally and with a narrow, shallow promontorium. The erismata are unusually short and widely divergent.

#### MEASUREMENTS (in mm).—

|           | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-----------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 728e |                            |                             |                  |                |                     |           |
| 151043c   | 22.8                       | ?                           | 27.3             | 17.8           | 9.7                 | 10.2      |
| 151043d   | ?                          | 27.1                        | 33.2             | 23.8           | ?                   | 10.0      |
| 151043e   | ?                          | 22.8                        | 29.5             | 19.3           | ?                   | 7.3       |
| 151043f   | ?                          | 23.0                        | 25.5             | 16.2           | ?                   | 8.7       |
| 151043g   | 17.0                       | 17.1                        | 22.6             | 16.0           | 6.0                 | 12.0      |
| 151043h   | 17.7                       | 16.0                        | 21.1             | 17.0           | 7.3                 | 10.2      |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower).

LOCALITIES.—AMNH 625, 629, 631, 632, 696, 699, USNM 728e, 728f, 728h, 741.

DIAGNOSIS.—Medium-sized *Meekella* with short interarea, incurved acute beak, and costae ranging from 14 to 22 in the adult.

TYPES.—Holotype: USNM 118514; figured hypotypes: 150894k, n, 151043a, 153517a-n.

COMPARISON.—*Meekella attenuata* most resembles *M. skenoides* Girty from the Word Formation and the Getaway Member of the Cherry Canyon Formation, but it differs in being less deep, in having

a less elongated interarea and fewer costae. *Meekella prionota*, new species, can be distinguished readily from *M. attenuata* by its more convex brachial valves, broad rounded plications, deep pedicle valve, and the broad sulcus of the brachial valve. *Meekella intermedia*, new species, occurs near the same stratigraphic level as *M. attenuata*, but it is deeper, with more elongated interarea and much more numerous costae.

DISCUSSION.—Although *Meekella attenuata*, like all *Meekellas*, is variable, its variability seems not to be so wide as that of many other species. Aside from the misshapen forms produced by crowding

and other consequences of an attached mode of life, the range of costation is not great, the interarea is seldom greatly elongated, and usually it maintains the same relationship to the commissure as is characteristic for the species. The number of bizarre and malformed specimens in our collection is small.

The broad-ribbed forms referred to *M. hessensis* by Stehli are herein placed in the synonymy of Girty's species. They have essentially the same form, the same costellate posterior, but the costae are less numerous. They are regarded as a paucicostate phase of *M. attenuata*.

### *Meekella calathica*, new species

PLATE 111: FIGURES 1-43; PLATE 112: FIGURES 1-24; PLATE 113: FIGURES 1-15; PLATE 114: FIGURES 11-26

*Meekella difficilis* R. E. King (not Girty), 1931:53, pl. 4: figs. 16a-d, 17, pl. 5: figs. 1a, 1b.

Adults large, biconvex, shallowly to deeply conical; outline transverse to nearly semicircular, ends of hinge prominently auriculate; hinge width proportionately constant, rarely outside limits of 0.5-0.8 of maximum width of shell. Plications of adults strong, fine to very coarse, normally fairly regular and not strongly interrupted by growth lines, with 1 or 2 on each valve bifurcating, numbering 6 to 21, averaging about 12, crests angular to subangular, not commonly rounded, beginning between 5 and 10 mm anterior to beaks. Costellae moderately strong, especially in nonplicate youthful stage, added by insertion in troughs of plications, anteriorly converging toward crests of plications; growth lines weak to moderately strong, more frequent anteriorly. Commissure rectimarginate coarsely serrate, with minute denticulation produced by anterior terminations of costellae.

Pedicle valve beak moderately sharp, short to moderately long, blunt to attenuate, often slightly twisted; interarea commonly much wider than long, normally gently concave toward beak but often convex in juveniles, nearly right angle in adults, but without sharp flexure; pseudodeltidium narrow, only slightly expanding dorsally, occupying between 0.2 and 0.33 total width of hinge, bisected by low narrow ridge.

Brachial valve moderately to strongly convex, maximum convexity near beak, plications equal in number and strength to those of pedicle valve. Interarea short.

Pedicle valve interior with short, strong teeth, triangular in cross section, projecting from underside of interarea, extending ventrally as nearly straight, convergent dental ridges supporting inside of interarea, then curving to floor of valve as dental plates, slightly bowed, ventrally convergent and normally anteriorly convergent, occasionally meeting and fusing at floor to form pseudospondylium.

Brachial valve with large, strongly curved cardinal process, strongly bifurcate at free end, each branch with long, finely serrate slit along posterior crest, branches uniting proximally to form subcarinate crest of process. Promontorium flat to slightly concave, projecting laterally from process and extending along it for somewhat more than half its length, terminating slightly beyond point of bifurcation of process, constricting proximally to accommodate deep and round hinge sockets; dentifers fused to cardinal process by gusset, projecting anterolaterally from it as small plates. Erismata strong, moderately divergent and forming deep umbonal chamber. Muscle area flabellate, in umbonal arch between dentifer supports, bisected by low myophragm; muscle marks obscure, consisting of longitudinal striae in muscle area and along bases of brachiophore supports.

## MEASUREMENTS (in mm).—

|                   | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|-------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 703a         |                                     |                                      |                          |                        |                             |                  |
| 150910a           | 47.7                                | 43.5                                 | 57.0                     | 28.8                   | 16.8                        | 34.6             |
| 150910b           | 48.8                                | 39.6                                 | 44.4                     | 29.8                   | 25.4                        | 37.0             |
| 150910c           | 30.8                                | 27.7                                 | 35.4                     | 27.3                   | 13.5                        | 27.5             |
| 150910d           | 24.8                                | 23.7                                 | 28.4                     | 18.9                   | 13.4                        | 22.7             |
| 150910e           | 31.0                                | 21.4                                 | 26.5                     | 19.8                   | 18.7                        | 18.8             |
| 150910f           | 23.8                                | 21.6                                 | 24.4                     | 16.0                   | 11.9                        | 22.8             |
| 150910g           | 21.0                                | 18.8                                 | 23.0                     | 18.9                   | 12.8                        | 20.0             |
| 150910h           | 23.7                                | 12.3                                 | 21.3                     | 15.8                   | 10.8                        | 20.7             |
| 150910i           | 17.4                                | 14.5                                 | 16.9                     | 13.4                   | 6.7                         | 11.7             |
| 150910j           | 15.2                                | 11.7                                 | 14.6                     | 8.6                    | 6.7                         | 9.1              |
| 150910k           | 12.7                                | 11.7                                 | 13.6                     | 9.3                    | 4.4                         | 9.3              |
| 150910-l          | 12.6                                | 10.3                                 | 12.3                     | 8.2                    | 12.2                        | 15.4             |
| 150910m           | 11.0                                | 9.3                                  | 11.0                     | 7.9                    | 3.6                         | 7.8              |
| 150910n           | 10.6                                | 8.3                                  | 8.9                      | 6.4                    | 4.6                         | 7.8              |
| 150910o           | 8.4                                 | 7.5                                  | 7.8                      | 5.1                    | 3.5                         | 5.2              |
| 150910p           | 5.5                                 | 5.5                                  | 6.5                      | 6.1                    | 4.1                         | 5.4              |
| 150910q           | 4.4                                 | 4.3                                  | 5.5                      | 4.7                    | 3.2                         | 4.0              |
| 150910r           | 4.8                                 | 3.7                                  | 4.6                      | 4.1                    | 2.2                         | 2.8              |
| USNM 702c         |                                     |                                      |                          |                        |                             |                  |
| 150909a           | 56.4                                | 50.4                                 | 58.5                     | 32.4                   | 15.0                        | 49.8             |
| 150909b           | 35.5                                | 35.5                                 | 46.4                     | 32.4                   | 15.0                        | 29.4             |
| 150909c           | 35.4                                | 34.2                                 | 41.8                     | 27.5                   | 12.9                        | 32.3             |
| USNM 702c         |                                     |                                      |                          |                        |                             |                  |
| 150909d           | 36.4                                | 30.0                                 | 33.5                     | 21.4                   | 17.8                        | 30.0             |
| 150909e           | 31.2                                | 27.8                                 | 36.0                     | 28.4                   | 15.8                        | 29.0             |
| 150909f           | 18.7                                | 14.9                                 | 19.0                     | 14.0                   | 10.7                        | 17.3             |
| 152604 (holotype) | 52.7                                | 50.6                                 | 52.8                     | 25.0                   | 14.0                        | 43.8             |
| USNM 702          |                                     |                                      |                          |                        |                             |                  |
| 150605a           | 41.3                                | 41.3                                 | 43.7                     | 27.0                   | 13.3?                       | 30.2             |
| 150605b           | 29.0                                | 28.6                                 | 30.5                     | 22.8                   | 13.4                        | 27.7             |
| 150605c           | 26.8                                | 24.0                                 | 29.7                     | 20.0                   | 8.4                         | 22.7             |
| 150605d           | 24.0                                | 22.5                                 | 27.2                     | 19.4                   | 8.0                         | 19.7             |
| 150605e           | 23.7                                | 20.3                                 | 25.5                     | 15.3                   | 7.0                         | 17.6             |
| USNM 702un        |                                     |                                      |                          |                        |                             |                  |
| 150607a           | 31.0                                | 31.0                                 | 35.6                     | 19.6                   | 10.4                        | 26.0             |
| 150607b           | 29.7                                | 28.8                                 | 34.0                     | 26.4                   | 10.5                        | 22.6             |
| 150607c           | 25.5                                | 24.8                                 | 29.1                     | 19.5                   | 12.8                        | 22.0             |
| 150607d           | 24.4                                | 21.5                                 | 26.6                     | 14.8                   | 6.7                         | 17.6             |
| 150607e           | 18.3                                | 17.2                                 | 20.6                     | 12.6                   | 5.2                         | 15.0             |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member), Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500, 500D, 500F, 500H, 500J, 500K, 500L, 500M, 500N, 500X, 504, USNM 702, 702a, 702b, 702ent, 702inst, 702-low, 702un, 703a<sup>1</sup>, 703b, 703bs, 708, 711q, 712o, 714v, 721u, 723u, 723y, 726o, 726u, 726x, 726y, 727p, 727w, 727x, 732u, 733m; Wedin: USNM 700-1, 700x, 714w, 717e, 723v; Road Canyon: AMNH 501, 503, USNM 700v, 702c, 703, 703a, 703c, 703d, 706f,

707e, 709c, 710u, 710z, 716x, 719x, 720d, 721j, 721o, 721r, 721t, 721w, 721s, 721t, 721w, 721x, 721y, 721z, 722e, 722f, 722g, 722v, 723a, 723w, 724a, 724b, 724c, 724d, 724j, 726d, 726f, 726z, 726za, 732m.

DIAGNOSIS.—Large *Meekella* with costellate umbones, pauciplicate exterior, and auriculate cardinal extremities.

TYPES.—Holotype: USNM 152604; figured paratypes: 150481a, b, 150484a-c, 150490a, b, 150605f, 150909b, f, 150910c, e, h, l, p-r, 153520a-g, 153521-153524, 153525a, b, 153526, 153527a, b, 153528a, b,

153529, 153530; measured paratypes: 150484a-m (plications counted), 150605a-e, 150607a-e, 150910a-r, 150909a-f, 152604; unfigured paratypes: 150605a-e, 150909a, c-e, 150910a, b, d, f-k, m-o.

COMPARISON.—*Meekella calathica* is characterized by its strong, normally regular plications, prominent auriculation of the ends of the hinge, wide interareas with sides that are concave in outline as they converge toward the slightly attentate beak, dental plates that normally are separate at their anterior ends, and its dentifers and promontorium that extend beyond the point of bifurcation of the cardinal process.

This species is distinguished from *M. irregularis* Schellwien and *M. texana* R. E. King by its normally shorter beak, much stronger and more regular plication that starts farther back on the beak, auriculate hinge, weaker costellae, and relatively longer brachiophores. Its strong plications distinguish it from *M. mexicana* Girty (from New Mexico), and it is distinguished from *M. caperata*, new species, and from *M. attenuata* Girty (from the Guadalupe and Diablo Mountains) by its coarser plications, less transverse outline, more auriculate hinge, and less attenuate beak.

*Meekella calathica* resembles *M. prionota*, new species, in its coarse plication, but it differs in its auriculate hinge, normally less conspicuous costellation, relatively longer dentifers, and normally narrower space between the dental plates. It is distinguished from *M. skenoides* Girty by its proportionately wider hinge and lower interarea,

slightly more prominent auriculation of the hinge, costellae that arch up to the crest of the plications, more variable coarseness of plication, and shorter dentifers and socket plates.

This species differs from *M. pyramidalis* (Newberry), from the Kaibab Formation, in its posteriorly curving beak rather than the anteriorly sloping beak that gives *M. pyramidalis* its pyramidal shape and from *M. occidentalis* (Newberry) and *M. grandis* King in its higher interarea, more transverse outline, and stronger convexity. Since Newberry's specimens are internal molds, further detailed comparison is meaningless.

DISCUSSION.—*Meekella calathica* varies most in its gross shape, strength of ornamentation, and in the number and coarseness of its plications. The shape may vary in degree of convexity, or in length of pedicle beak, strength of auriculation of hinge, width of interarea or the angle at which the interarea intersects the plane of commissure. Plications vary in strength, coarseness, and number with none of these factors directly dependent upon the size of the shell (except, of course, in the smallest of juveniles). Thirty-five complete shells were selected from samples from USNM 702c and one pedicle valve from USNM 702 with selection based on uniformity of size. All 36 are between 20 and 32 mm in maximum width. This group includes about all of the complete shells of that size in sample 702c. The following table shows the number of plications on these specimens:

|                      |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |
|----------------------|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|
| number of plications | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| number of specimens  | 1 | 1 | 2 | 3 | 2  | 5  | 7  | 7  | 3  | 2  | 1  | 0  | 1  | 0  | 0  | 1  |

The largest specimen of this group, 32 mm wide, has 8 plications. The largest specimen in the national collection is 59 mm wide and has only 14 plications. Coarseness and strength of plications depends upon the number present: with many present, each must be finer and somewhat weaker in order to fit on the shell. When viewed beside one another, the end members of the above selected group are so different from one another that they appear to belong almost certainly to separate species. But all stages of transition between the extremes may be found in any large sample (e.g., USNM 702c or 703a), and a count of plications in a randomly selected group produces a normal curve.

Some specimens of *M. calathica* have unusually strong growth lines and costellae that produce a reticulate or woven effect over the surface of the shell. Many of the shells with this stronger ornamentation are more than ordinarily auriculate and have lower convexity of the pedicle than do those with weaker ornamentation. All degrees of transition are present, however, and so many shells are intermediate that the population cannot be divided into two groups that are sufficiently distinct to warrant naming of the reticulate type, not even as a variety of *M. calathica*.

*Meekella difficilis* of R. E. King (1931:53), but not of Girty (1909), has all of the diagnostic char-



acteristics of *M. calathica* and is not conspecific with the holotype of *M. difficilis* Girty (USNM 118510). The specimens illustrated by King (1931, pl. 4: figs. 16, 17; pl. 5: fig. 1) are more coarsely plicate than most specimens of *M. difficilis*, but they agree in all respects with numerous specimens of *M. calathica* in our collections. Furthermore, *M. "difficilis"* of King occurs in the Leonard Formation, whereas *M. difficilis* Girty (now a synonym of *M. skenoides* Girty) is present in the Word Formation.

### *Meekella caperata*, new species

PLATE 89: FIGURES 11–13; PLATE 105: FIGURES 10–34

Small to medium biconvex, deeply conical; outline transversely subelliptical; hinge straight, between two-thirds and three-fourths maximum width, normally not auriculate. Plications fine but strong, rounded, fairly regular, increasing in number anteriorly by bifurcation and intercalation, numbering between 14 and 40, beginning 5 to 15 mm anterior to beaks. Costellae very fine, strongest on unplicated part of umbo; growth lines faint, increasing in frequency anteriorly.

Pedicle valve beak sharp, normally attenuated, commonly twisted; interarea long, wide, nearly flat, commonly meeting plane of commissure at obtuse angle, rarely at acute angle; pseudodeltidium narrow, not widening anteriorly as fast as interarea,

measuring about one-fourth width of interarea at hinge, bisected by narrow but fairly high median ridge.

Brachial valve moderately convex; beak slightly overhanging pedicle interarea; plications equal in number and strength to those on pedicle valve.

Pedicle valve interior with short, strong hinge teeth, extending posteriorly as convergent dental ridges; dental plates convergent toward valve floor, extending forward along floor only short distance; normally separate along floor of valve, but rarely fusing to form pseudospondylium, muscle marks obscure.

Brachial valve interior with moderately long, curved cardinal process, bifurcate at distal end, each branch slit longitudinally and finely serrate within slits; branches united about midway along process to form crest along proximal half; promontorium projecting only slightly from sides of process, to form crest along proximal half; promontorium projecting only slightly from sides of process, terminating proximally as enlarged bosses just anterior to partly open sockets; dentifers fused to sides of process ending distally as 2 short apophyses from underside of cardinal process, widening dorsally to join with erismata, as supports into umbonal arch, there outlining posterior end of muscle area. Muscle field bilobed, bisected by low myophragm; adductor scars longitudinally striate within muscle area and along bases of erismata.

#### MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 705a          |                            |                             |                  |                |                     |           |
| 150499a            | 9.6                        | 9.6                         | 11.5             | 8.0            | 7.4                 | 10.0      |
| 150499b            | 13.0                       | 11.0                        | 14.5             | 8.8            | 7.6                 | 9.9       |
| 150499c            | 16.9                       | 15.9                        | 22.5             | 16.5           | 13.0                | 18.6      |
| 150499d            | 24.2                       | 21.7                        | 24.9             | 17.4           | 16.5                | 20.2      |
| 150499e            | 32.5                       | 25.2                        | 32.7             | 20.7           | 21.8                | 23.7      |
| 150499f (holotype) | 29.4                       | 29.4                        | 39.7             | 25.0           | 19.8                | 32.0      |
| USNM 707w          |                            |                             |                  |                |                     |           |
| 150503             | 24.4                       | 24.4                        | 28.3             | 16.2           | 16.0                | 24.1      |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Cibolo Formation.

LOCALITIES.—Decie Ranch: USNM 707a, 707w, 724p, 733h; Poplar Tank: 707h; Sullivan Peak: 707; Skinner Ranch (base): 705a, 720e; Cibolo: 738r.

DIAGNOSIS.—Large *Meekella* with elongated pedicle valve and fine plications.

TYPES.—Holotype: USNM 150499f; figured paratype: 150499a, c, f, 150500, 151026, 153531a–d, 153546; measured paratypes: 150499a–e, 150503; unfigured paratypes: 150499b, d, e.

COMPARISON.—*Meekella caperata* is characterized by its numerous, fine, frequently bifurcating plications that do not begin as far back as the beak, nonauriculate hinge, attenuate pedicle beak and short dental plates. It differs from all other species in the Glass Mountains except *Niviconia globosa* (R. E. King) in the fineness and large number of its plications. It differs from *N. globosa* in its greater maximum number of plications that do not extend to the ends of the beaks, its nonauriculate hinge, more transverse outline, and conventionally attached promontoria that do not form troughs along the sides of the cardinal process.

DISCUSSION.—R. E. King (1931:53) mentions a specimen with 38 plications from his locality 38 (basal Leonard, Decie Ranch Member of Skinner Ranch Formation) that he identified as *M. attenuata* Girty. Undoubtedly the specimen belongs to *M. caperata*, inasmuch as only that species has so many plications.

Probably many specimens identified by King as *M. attenuata* Girty actually belong to *M. caperata*, although most of the specimens illustrated by him as *M. attenuata* are *M. skenoides* Girty (King, 1931, pl. 5: figs. 2, 4, 5, 7) or *M. calathica*, (pl. 5: fig. 3); however, his description of *M. attenuata* best fits a species with many fine plications. There is little basis for identifying anything outside the Bone Spring Formation with *M. attenuata* Girty. The holotype is a juvenile with only 10 weak plications instead of the "15 to 25" attributed to the species by Stehli (1954:304) or the "11 to 28 strong, sub-angular plications" that R. E. King (1931:53) said characterize the species. Girty's paratypes (three specimens, USNM 118507a-c) are poorly preserved and show a maximum of 14 weak plications; they are not specifically identifiable by present standards.

It is impossible to obtain topotype specimens that might shed light on the identity of the holotype, because the locality from which that specimen was collected is unknown (Girty, 1909:512, data on USGS 3764).

### *Meekella circularis*, new species

PLATE 101: FIGURES 1-8

Very large for genus, crudely subcircular in outline, length and width nearly equal in adults. Sides and anterior broadly rounded; maximum width near midvalve. Hinge narrower than maximum width, about two-thirds width. Interarea short, curved, approximately catacline. Pseudodeltidium broad and low on brachial valve, somewhat stronger on pedicle valve and numbering 8 to 14. Plications mostly direct, some bifurcating. Entire surface covered by strong costellae in grooves and on plications. Pedicle valve gently convex in lateral profile, most convexity in posterior, flattened anteriorly; anterior profile broadly and moderately domed. Umbonal region moderately swollen; median region gently convex to flattened. Posterolateral slopes steep. Brachial valve moderately strongly, evenly convex in lateral profile; broadly and moderately domed in anterior profile. Umbonal region slightly swollen; median region and sides swollen; lateral and anterior slopes fairly steep. Pedicle valve interior with large teeth and strong dental ridges, dental plates short, receding and convergent, barely uniting on floor in large adults but narrowly separated in young. Brachial valve interior with moderately long, wide cardinal process with short narrowly separated prongs. Promontorium small, fulcral plates small. Erismata long, widely flaring. Adductor scars large and subflabellate.

#### MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| AMNH 700           |                            |                             |                  |                |                     |           |
| 152613a            | 15.5                       | 15.0                        | 19.6             | 13.0           | 6.1                 | 11.4      |
| 152613b            | 20.5                       | 18.5                        | 24.6             | 17.6           | 5.0                 | 12.2      |
| 152613c            | ?                          | 30.5                        | 38.7             | 23.0*          | ?                   | 11.3      |
| 152613d (holotype) | 52.2                       | 51.9                        | 62.4             | 44.1           | 18.8                | 40.9      |
| USNM 725b          |                            |                             |                  |                |                     |           |
| 152614a            | 28.9                       | ?                           | 35.0             | 24.2           | 8.6                 | ?         |
| 152614b            | ?                          | 28.0                        | 37.3             | 24.7           | ?                   | 8.8       |

STRATIGRAPHIC OCCURRENCE.—Hueco Formation.  
LOCALITIES.—AMNH 700, USNM 725a, 725b.

DIAGNOSIS.—Large *Meekella* with subdued plications on the brachial valve and short convergent dental plates.

TYPES.—Holotype: USNM 152613d; unfigured measured paratypes: 152613a–d, 152614a, b.

COMPARISON.—This species is best compared with the huge *Meekellas*: *M. enormis*, new species; *M. occidentalis* (Newberry); *M. calathica*, new species; and *M. magnifica*, new species. Adults are smaller than *M. enormis* and have a much shorter pedicle valve interarea; they are less strongly plicated than *M. occidentalis* and more convex on the brachial side; they are less convex on both valves and less strongly and deeply plicated on both valves than *M. calathica*.

This species resembles *M. magnifica* in its robust form, but it is not as large as that species, has much more subdued ornament, a rounder outline, and a much less extended beak and interarea.

*Meekella enormis*, new species

PLATE 69: FIGURES 10–12; PLATE 106: FIGURES 1–25; PLATE 107: FIGURES 1–17

Very large for genus, deeply conical, wide hinged, transversely elliptical in dorsal outline. Interarea broad, nearly at right angles to the lateral commissure; hinge width varying between 0.6 and 0.75 of maximum width. Cardinal extremities slightly auriculate. Sides unevenly rounded, greatest width at midvalve or slightly anterior; anterior commis-

sure faintly sulcate, especially in juveniles. Surface plicate, plications unequal in size on valves, on brachial valve more distant and lower in adults; plications rounded, often irregular, few bifurcating, averaging about 13, ranging from 10 to 21 on largest specimens. Fine costellae strong, numbering 3 per mm near front of large specimens.

Pedicle valve unevenly and moderately convex in lateral profile, moderately domed in anterior profile; interarea moderately long usually with slight concavity near beak. Pseudodeltidium equal about one-fourth the hinge width, strong monticulus in old shells with strong lateral ridges. Beak ridges strong, elevated, defining concave flanks. Young specimens weakly folded, obscure in adults.

Brachial valve evenly and moderately convex in lateral profile, broadly and moderately convex in anterior profile; umbonal region moderately swollen, extending slightly posterior to hinge; interarea short or obsolete; umbonal slopes short and moderately steep; sulcus shallow and broad in young, not clearly visible in large specimens.

Pedicle valve interior with small teeth; strong receding dental plates, well separated in the young but converging to form pseudospondylium in old specimens and in aberrant individuals. Muscle field large, strongly flabellate, anterior rim thickened in oldest adults, reaching nearly to midvalve, well outside delthyrial cavity.

Brachial valve interior with cardinal process moderately elongated, moderately spreading, dentifiers well developed, erismata short in young, long and thick in adults.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720e          |                            |                             |                  |                |                     |           |
| 150890a            | 7.5                        | 6.6                         | 7.8              | 6.1            | 4.2                 | 5.9       |
| 150890b            | 9.7                        | 9.7                         | 11.5             | 9.8            | 4.9                 | 8.0       |
| 150890c            | 11.7                       | 10.3                        | 13.2             | 9.3            | 8.2                 | 12.0      |
| 150890d            | 17.4                       | 15.3                        | 18.0             | 11.2           | 6.7                 | 15.2      |
| 150890e            | 18.4                       | 18.4                        | 24.8             | 14.9           | 9.1                 | 15.2      |
| 150890f            | 27.4                       | 20.1                        | 24.0             | 17.9           | 14.8                | 17.8      |
| 150890g            | 22.1                       | 21.6                        | 26.7             | 18.2           | 9.5                 | 18.5      |
| 150890h            | 27.6                       | 25.2                        | 32.1             | 21.0           | 11.2                | 23.8      |
| 150890i            | 26.7                       | 25.6                        | 30.6             | 22.8           | 20.7                | 31.8      |
| 150890j            | 31.7                       | 27.6                        | 36.6             | 27.4           | 16.0                | 29.8      |
| 150890k            | 35.0                       | 31.0                        | 36.6             | 27.3           | 13.7                | 26.6      |
| 150890–l           | 32.0                       | 32.0                        | 40.3             | 28.0           | 11.7?               | 25.0      |
| 150890m            | 49.4                       | 49.4                        | 57.0             | 44.4           | 33.9                | 51.0      |
| 150890n (holotype) | 65.0                       | 60.5                        | 79.5             | 51.0           | 25.5                | 55.8      |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members).

LOCALITIES.—Decie Ranch: USNM 707a, 707w, 714t; Poplar Tank: 707h; Sullivan Peak: 707v; Skinner Ranch (lower): 705a, 714q, 716t, 720e.

DIAGNOSIS.—Very large *Meekella* with exaggerated ornament on pedicle valve and an elevated diductor muscle margin in the pedicle valve.

TYPES.—Holotype: USNM 150890n; figured paratypes: 150596, 150889, 150890c, e, g, i, j, m, 153448a–c; measured paratypes: 150890a–m; unfigured paratypes: 150890a, b, d, f, h, k, l, 153448b.

COMPARISON.—This species attains the largest size of any *Meekella* found in the Glass Mountains and approaches the large species found in the Permian of Japan, *M. gigantea* Hayasaka 1933 (not Stuckenberg, 1905). This species suggests *M. occidentalis* (Newberry), which attains a large size as seen in its synonym *M. grandis* King. This species differs from *M. calathica*, new species, in having lower plications, the plications less differentiated on the two valves, usually having much less thickness in the large adults, a longer and narrower beak, narrower pseudodeltidium, more fully umbonate brachial valve, and generally narrower hinge.

Some young specimens of *M. enormis* suggest relationship to *M. hessensis* R. E. King, and the number and arrangement of plications accords with those of *M. enormis*. *Meekella hessensis* is, however, wider than *M. enormis*, and *M. hessensis* occurs at the top of the Skinner Ranch Formation rather than at its base. The holotype of *M. hessensis* is the only reliable specimen of the species known, and that has no beak. It is difficult, therefore, to make a satisfactory determination with the *M. enormis* ranging in size from 7.5 mm to 65 mm in length.

DISCUSSION.—Unusual features of this genus are the difference in the ornament of the two valves and the enormous development of the diductor muscle area inside the pedicle valve of adults. The difference in ornament is seen best in the large adults, but it is not as clear in the smaller specimens or in very young forms. Plications of the pedicle valve normally are closely crowded, irregular, and subangularly rounded. At the anterior of the large specimens the plications are broadened and the furrows between them are much narrower.

On the brachial valve, on the other hand, plications are much lower and are spread farther apart so that the troughs between them are broader. Spasmodic bifurcation of plications occurs on both valves, but it is more prominent on the pedicle valve.

No unusual features are presented in the growth of this species; it is variable at all stages. The non-plicate stage is fairly short. The smallest measured specimen is 7.5 mm in length and does not exhibit any well-marked plications. The next longer specimen, about 10 mm, is fairly well plicated about 7 mm from beak. As usual with attached forms, length and width are very unreliable measures. One odd specimen is fairly wide and suggests *M. hessensis*.

*Meekella enormis* lived closely crowded among large specimens of *Scacchinella* and *Derbyia*, usually liberally covered by bryozoa and other calcareous material (assumed algal). Some specimens are literally buried in encrusting material, which must have been lethal; others are riddled by borings of acrothoracic barnacles (Schludt and Young, 1960:905). Some shells are so greatly riddled as to be almost destroyed.

### *Meekella hessensis* R. E. King

PLATE 108: FIGURES 11–31

*Meekella hessensis* R. E. King, 1931:56, pl. 5: figs. 8, 9.

Medium size for genus, outline transversely elliptical, widest near midvalve; hinge about two-thirds width; sides strongly rounded; anterior margin broadly rounded; anterior commissure usually rectimarginate to faintly sulcate. Interarea short to moderately long, usually nearly catacline. Plications variable, usually narrowly angular, separated by equally wide troughs, in some adults abruptly widening and flattening, and occasionally bifurcated or intercalated, numbering 7–16. Juveniles strongly costellate until reaching 5–7 mm when plication originates; costellae strong over body of shell, diverging laterally in troughs of adults.

Pedicle valve flat to slightly convex in lateral profile often with break in slope where plications expand suddenly; broadly and moderately convex in anterior profile; umbonal region flattened to gently convex; beak blunt, usually forming wide angle; median region varying from flattened to con-

cave to gently convex; flanks moderately steep. Pseudodeltidium flat, narrow with elevated monticulus.

Brachial valve evenly and gently convex in lateral profile, greatest convexity at umbo of adults and large specimens; broadly and moderately convex in anterior profile; median region moderately inflated, median sulcus shallow, only faintly visible at anterior; umbo gently to moderately swollen, protruding slightly beyond posterior margin; lateral and anterior slopes usually gently convex, sloping

gently to margins.

Pedicle valve interior with short receding dental plates reaching about one-third valve length, dental plates forming narrow, parallel track on valve floor. Teeth small, sharp.

Brachial valve interior with long and fairly wide cardinal process; prongs short, subparallel; denticles long, almost reaching ends of cardinal process; erismata long, moderately wide. Promontorium well developed. Muscles marks not impressed.

#### MEASUREMENTS (in mm).—

|                      | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|----------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| King 122             |                            |                             |                  |                |                     |           |
| YPM 10950 (holotype) | 27.7+                      | 24.6                        | 34.4             | 23.4           | ?                   | 18.5?     |
| USNM 702e            |                            |                             |                  |                |                     |           |
| 152608a              | 22.1                       | 21.8                        | 27.3             | 16.7           | 7.0                 | 17.4      |
| 152608b              | 11.8                       | 11.3                        | 13.4             | 8.9            | 5.5                 | 8.0       |
| 152608c              | 8.5                        | 7.7                         | 9.0              | 6.4            | 4.1                 | 5.7       |
| USNM 702f            |                            |                             |                  |                |                     |           |
| 152609               | 23.5                       | 22.9                        | 25.8*            | 15.0           | 3.5                 | 16.5      |
| AMNH 369             |                            |                             |                  |                |                     |           |
| 152610               | 22.5                       | 21.4                        | 26.6             | 14.3           | 6.2                 | 21.3      |
| USNM 722-1           |                            |                             |                  |                |                     |           |
| 152611a              | 25.4                       | ?                           | 31.8             | 22.3           | 10.6                | 12.0?     |
| 152611b              | ?                          | 29.4                        | 36.0             | 25.0           | ?                   | 11.2      |
| 152611c              | 14.5                       | 12.9                        | 17.3             | 10.3           | 3.7                 | 11.8      |
| USNM 725c            |                            |                             |                  |                |                     |           |
| 152612a              | 21.4                       | 20.2                        | 25.1             | 15.8           | 7.0                 | 15.5      |
| 152612b              | 16.8                       | 15.8                        | 18.5             | 14.6           | 7.0                 | 15.2      |
| 152612c              | 9.7                        | 9.4                         | 11.7             | 8.9            | 5.0                 | 7.8       |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Hess Formation (Taylor Ranch Member), Skinner Ranch Formation (Decie Ranch, Poplar Tank, Sullivan Peak, and Dugout Mountain members).

LOCALITIES.—Bone Spring: AMNH 369, 492, 497, 591, 624, 628, 658, 660, 697, USNM 725c, 725s, 725y, 728e, 728f, 728g, 728v, 729, 745; Hess: R. E. King 122, USNM 722n, 726n; Decie Ranch: USNM 707a, 720g; Poplar Tank: USNM 707ha, 708e; Sullivan Peak: USNM 705o, 707b, 707c, 707d, 707g, 707-1, 722h, 722-1, 727a, 733j; Dugout Mountain: USNM 732e; Skinner Ranch: AMNH 520, USNM 723o; Skinner Ranch (lower): USNM 705a, 709v, 711p, 712p, 714p, 715n, 715v, 716t, 720e, 720f, 720g, 727f; Skinner Ranch (upper): USNM 705r, 714y, 723h,

723-1, 723o; Taylor Ranch: USNM 702d, 702e, 702f, 716m.

DIAGNOSIS.—Transversely elliptical *Meekella* with short, conical pedicle valve, variable number of plications, and strong costellation, especially in the young stages.

TYPES.—Holotype: YPM 10950; figured hypotypes: USNM 152608a, 152610, 152611a, b; measured hypotypes: USNM 152608a-c, 152609, 152610, 152611a-c, 152612a-c.

COMPARISON.—*Meekella hessensis* is characterized by its transverse outline, generally short, nearly catacline beak, and distinctive ornament. Posteriorly it has a costellate stage representing the young form, but the costellae are strong, prominent, and tend to maintain considerable strength over the



plicated body of the shell. The plications are usually narrowly angular, but they are variable. In some specimens an interruption in growth produced lower, broader, but still angular costae. It resembles some forms of *M. occidentalis* (Newberry), but it is somewhat wider proportionately than most specimens of that species of the same size. Furthermore, its beak is generally blunter and the interarea short and flat.

DISCUSSION.—R. E. King figured two specimens, a holotype, designated by him, and a paratype. The latter is more strongly costate than the holotype and represents the more broadly plicate form of the species. The holotype comes from the upper part of the Skinner Ranch Formation; the paratype is from the Taylor Ranch Member of the Hess Formation.

*Meekella intermedia*, new species

PLATE 105: FIGURES 1–9

Medium size for genus, subconical lateral profile but subcircular dorsal profile, maximum width at about midvalve. Sides somewhat narrowly rounded; anterior margin broadly rounded. Anterior commissure usually with broad wave toward ventral

side. Costae abundant, narrow, subangular, numbering about 30 in large adults. Beak region costellate for about 10 mm, costae arising from enlargement of 1 costella, or union of 2 or 3. Fine costellae not reaching anterior margin.

Pedicle valve triangular, lateral profile unevenly convex on long side, maximum convexity near midvalve; anterior profile moderately domed. Beak acute; interarea moderately long, slightly concave, pseudodeltidium narrow, about one-third hinge width. Median region forming poorly defined fold.

Brachial valve unevenly convex in lateral profile, greatest convexity on posterior half, anterior half somewhat flattened. Anterior profile broadly and moderately convex. Umbonal region swollen, umbonal slopes steep; anterior median region depressed into shallow broad sulcus, flanks gently swollen. Interarea not noticeably developed.

Pedicle valve interior with strong dental plates, slightly receding, convergent ventrally but usually fairly widely separated.

Brachial valve interior with moderately long cardinal process supported by short, strong, widely flaring erismata; distal prongs not separated; shaft with strong axial keel; promontorium narrow. Myophragm small, located near apex.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 728f          |                            |                             |                  |                |                     |           |
| 150902a (holotype) | 25.7                       | 21.8                        | 26.4             | 14.4           | 8.7                 | 17.4      |
| 150902b            | 28.9                       | ?                           | 28.8             | 19.6           | 13.4                | 14.6      |
| 150902c            | ?                          | 31.0                        | 36.7             | 23.0           | ?                   | 10.2      |
| 150902d            | 25.0                       | ?                           | 27.5             | 18.0           | 12.7                | 11.2      |
| 150902e            | ?                          | 25.8                        | 29.0             | 16.8           | ?                   | 11.0      |
| 150902f            | 20.2                       | ?                           | 20.0             | 13.1           | 9.3                 | 13.0      |
| 150902g            | ?                          | 20.5                        | 23.8             | 13.7           | ?                   | 8.0       |
| 150902h            | 15.5                       | ?                           | 17.8             | 13.0           | 5.7                 | 6.8       |
| AMNH 629           |                            |                             |                  |                |                     |           |
| 152603a            | 23.0                       | ?                           | 24.0             | 13.4           | 11.0                | 10.5      |
| 152603b            | ?                          | 21.4                        | 26.0*            | 14.8           | ?                   | 13.9      |
| AMNH 628           |                            |                             |                  |                |                     |           |
| 150906             | 20.8                       | 19.0                        | 23.3             | 14.0           | 7.7                 | 14.8      |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (base).

LOCALITIES.—AMNH 625, 628, 629, 631, USNM 725e, 728f, 728h, 745, 746.

DIAGNOSIS.—*Meekella* with subangular costae and short interarea.

TYPES.—Holotype: USNM 150902a; figured paratypes: 150902b, c; measured paratypes: 150902b–h, 150906, 152603a, b; unfigured paratypes: 150902d–h.

COMPARISON.—The exterior of this species resembles that of *M. angustiplicata*, new species, but *M. intermedia* has fewer costae. The ribbing of

*M. angustiplicata* is so fine that the species can not be confused with any other species. *Niviconia globosa* is also readily distinguished from *M. intermedia* by its longer interarea, more convex brachial valve, and the greater differentiation between costellae and costae at the posterior. Furthermore, the cardinal process of *M. intermedia* never attains the ponderous character and great elongation of *N. globosa*.

DISCUSSION.—This species is rare in the Bone Spring Formation. Its shells are usually thin, delicate, and difficult to recover. The development of costae can be observed well in this species. The young shell at about 10 mm length is fairly evenly costellate with about three or four costellae per mm. One or two of the four costellae will be larger than the others. Anteriorly some of these swell to produce a costa, while two or three may unite to form a single costa. Other costellae follow the troughs between the costellae and ultimately disappear. At the anterior margin of the holotype, fine costellae are rare on the costae, most of which exhibit strong, crowded growth lines.

### *Meekella magnifica*, new species

PLATE 100: FIGURES 1–33; PLATE 116: FIGURES 9–18

*Meekella mexicana* R. E. King (not Girty), 1931:55, pl. 7: figs. 1–5.

Large, biconvex, shallow to deeply and irregularly conical; outline semicircular to transversely subelliptical; hinge straight, width between 0.5 and 0.99 maximum shell width, meeting lateral curve of shell outline at right or obtuse angle with only slight auriculation of hinge extremities. Plications numbering 7 to 21, averaging about 15, rounded on crests, uneven and irregular, interrupted by growth lines, normally one or two plications on each valve bifurcating; plications beginning 5 to 25 mm anterior to pedicle beak, averaging about 15 mm, hence, juvenile shells unplicated. Costellae strong, especially on unplicated area near beak, increasing in number anteriorly by insertion, continuing straight forward, converging toward crests of plications only near anterior margin of large shells. Growth lines weak on some shells, stronger on others, becoming stronger and more frequent anteriorly; commissure coarsely plicate, each plication finely serrate at anterior ends of costellae.

Pedicle valve beak blunt, commonly twisted, interarea wide, long, or short, depending on growth conditions, longitudinally flat or concave, rarely convex, with posterior hook near apex in mature individuals, meeting plane of commissure at obtuse angle in young shells, nearly at right angle in mature shells; pseudodeltidium sharply or vaguely delimited from lateral parts of interarea, its edges marking traces of forward growth of hinge teeth; width at hinge about one-third or slightly less than hinge width; bisected by narrow ridge of nearly uniform width.

Brachial valve lidlike, moderately to strongly convex, interarea short; beak slightly overhanging pedicle interarea; plications equal in number to those on pedicle valve, normally somewhat weaker.

Pedicle interior with strong teeth extending posteriorly as convergent dental ridges supporting underside of interarea, then near beak curving to floor of valve and extending forward as slightly divergent dental plates. Some specimens with callus of adventitious shell thickening beneath pseudodeltidium and between dental ridges. Many specimens with outwardly bowed, convergent dental plates meeting and fusing throughout their length along valve floor, forming pseudospondylium; most individuals with straight, anteriorly divergent dental plates, separate at anterior ends, but commonly fused posteriorly near beak by deposit of adventitious shell material. Muscle marks between dental plates, making low corrugations on inner sides of plates.

Brachial valve hinge surface shallowly concave, providing bearing-edge for articulation of pedicle hinge. Cardinal process long, strong, inwardly bowed, projecting ventrally; free and bifurcate, each branch with minutely serrate longitudinal slit along posterior edge. Dentifers flat, bladelike, projecting from sides of process and nearly parallel to it, terminating abruptly ventrally where process bifurcates, constricted dorsally just anterior to deep circular dental sockets. Erismata short, widely divergent. Muscle area between erismata bisected by low median ridge; muscle marks obscure, consisting of faint irregular striae in muscle area and along bases of brachiophore supports.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701g          |                            |                             |                  |                |                     |           |
| 150578a            | 4.2                        | 5.0                         | 7.0              | 6.2            | 2.9                 | 3.9       |
| 150578b            | 9.0                        | 4.6                         | 6.0              | 5.6            | 5.9                 | 5.5       |
| 150578c            | 9.0                        | 6.0                         | 8.7              | 5.2            | 3.8                 | 4.4       |
| 150578d            | 12.0                       | 7.3                         | 8.8              | 6.5            | 6.7                 | 7.8       |
| 150578e            | 7.8                        | 6.5                         | 8.7              | 6.9            | 3.6                 | 5.0       |
| 150578f            | 11.4                       | 9.6                         | 12.5             | 9.8            | 7.4                 | 9.4       |
| 150578g            | 9.7                        | 9.0                         | 12.5             | 9.6            | 4.7                 | 6.5       |
| 150578h            | 14.0                       | 10.7                        | 15.0             | 10.3           | 4.7                 | 8.8       |
| 150578i            | 16.0                       | 11.8                        | 15.4             | 9.4            | 5.7                 | 10.0      |
| 150578j            | 25.5                       | 14.3                        | 18.0             | 13.6           | 12.5                | 13.0      |
| 150578k            | 20.9                       | 13.3                        | 18.5             | 14.6           | 10.8                | 11.6      |
| 150578-l           | 16.0                       | 12.7                        | 17.8             | 13.4           | 7.6                 | 10.4      |
| 150578m            | 18.9                       | 15.4                        | 31.0             | 17.4           | 5.4                 | 14.0      |
| 150578n            | 22.0                       | 15.7                        | 23.0             | 15.8           | 7.7                 | 3.5       |
| 150578o            | 23.2                       | 20.2                        | 25.8             | 17.5           | 10.3                | 7.9       |
| 150578p            | 20.5                       | 18.7                        | 25.8             | 17.5           | 9.6                 | 15.8      |
| 150578q            | 26.0                       | 24.6                        | 29.0             | 20.0           | 11.7                | 23.0      |
| 150578r            | 28.8                       | 26.0                        | 31.5             | 19.8           | 16.9                | 29.0      |
| 150578s            | 32.7                       | 23.5                        | 33.0             | 22.7           | 17.2                | 26.8      |
| 150578t            | 29.8                       | ?                           | 40.6             | 31.0           | 18.2                | 21.4      |
| 150578u            | 28.5                       | ?                           | 32.0             | 29.3           | 23.4                | 26.0      |
| 150578v            | 31.5                       | ?                           | 41.8             | 34.0           | 23.4                | 24.8      |
| 150578w            | 46.0                       | ?                           | 41.5             | 34.8           | 39.3                | 41.3      |
| 150578x (holotype) | 46.9                       | 43.4                        | 48.6             | 40.0           | 36.0                | 49.0      |
| 150578y            | 49.7                       | ?                           | 49.7             | 41.7           | 21.3                | 39.6      |
| USNM 701a          |                            |                             |                  |                |                     |           |
| 150570             | 54.4                       | 49.0                        | 62.3             | 47.8           | 29.7                | 50.8      |

Ranch Formation (bed 2 of R. B. King), Neal Ranch Formation (beds 2–14), Lenox Hills Formation.

LOCALITIES.—*Uddenites*: USNM 701x; Neal Ranch (bed 2); USNM 701; (beds 9–14): USNM 701a, 701a<sup>1</sup>, 701c, 701g, 715e; Lenox Hills: USNM 705, 705s, 707j, 709t, 709w.

DIAGNOSIS.—Large irregularly plicate *Meekella* with broad and long interarea having a long non-plicate youthful stage.

TYPES.—Holotype: USNM 150578x; figured paratypes: 150570, 150577, 153535a–c, e, g, 150578a, g, j, q, r; measured paratypes: 150570, 150578a–w, y; unfigured paratypes: 153535d, f, 150578b–f, h, i, k–p, s–w, y, 153535d.

COMPARISON.—*Meekella magnifica* is characterized by its large maximum size, irregular and rounded plications, averaging about 15 in number, that begin far forward from the beak, relatively strong costellation, and normally nonconvergent

dental plates. Large specimens are distinguished also by their wide hinges, with consequent wide and normally long interareas that meet the plane of commissure at nearly a right angle. The beak of a large shell normally hooks posteriorly, the result of the meeting of interarea and commissure at an obtuse angle in the juvenile shell. The anterior profile of the pedicle valve normally is only slightly convex, straight or slightly concave, analogous to that of *Tropidelasma culmenatum*, new species.

*Meekella magnifica* differs from *M. irregularis* Schellwien by its stronger plications, especially on the brachial valve, proportionately wider delthyrium and longer interarea (longer beak), or proportionately narrower hinge, and also apparently by its more convex brachial valve. It differs from *M. mexicana* Girty by its normally longer and blunter beak, longer and wider interarea, and coarser, normally deeper plications.

Among other species of *Meekella* from the Glass

Mountains, *M. magnifica* differs from *M. occidentalis* (Newberry) (= *M. grandis* R. E. King) by its much weaker plication, stronger costellation, normally longer beak in large individuals, proportionately shorter dentifers, and especially by its lack of a strongly flared hinge that produces ears at each end of the hinge. It differs from *M. attenuata* Girty and *M. caperata*, new species, by its fewer and much coarser (although not necessarily stronger) plications. It may be distinguished from *M. skenoides* Girty by its larger maximum size, more irregular shape, weaker and more rounded and irregular plications, and somewhat lower interarea, i.e., proportionately wider hinge. It differs from large pauciplicate forms of *M. grandis* in its normally longer interarea and greater convexity, and weaker, more irregular plications that begin farther from the beak. These differences become increasingly apparent in the larger shells; a large pauciplicate *M. grandis* is very broad, and the pedicle valve is a low cone, whereas a large individual of *M. magnifica* is very deeply conical.

*Meekella magnifica* is an unusually variable species of a genus in which wide variation is the rule. The most drastic differences are not between individuals at a particular stage of growth, but between specimens at different stages. The stage of growth of a specimen often may be recognized by its size, although size alone is not the most reliable criterion. Some specimens appear to have matured while maintaining a relatively small size, and others seem to have remained juveniles to a rather large size. Juveniles normally have the interarea meeting the plane of commissure at an obtuse angle, which lessened gradually to a right angle as the individual matured, thus producing a posterior hook on the beak of mature individuals. In some the angle remained obtuse and the shell relatively unplicated and marked only by weak growth lines to a size of 35 mm (maximum height). Other specimens have the hook beginning only 4 or 5 mm forward of the beak and have the coarser plications and prominent growth lines characteristic of maturity while having attained a maximum height of only 20 mm. Unplicated or faintly plicated individuals, especially those with short beaks, are the same as King's *M. "mexicana."* The point of maxi-

mum flexure of the interarea in most individuals is about the same distance forward as the beginning of plication. This is not consistently true of other species of *Meekella* in the Glass Mountains.

Dental plates in *Meekella magnifica* are strong, normally straight, and converge slightly toward the floor of the valve without meeting. Many mature shells, however, have dental plates that bow away from the axial plane, and then converge strongly toward the floor, meeting and fusing there to form a sessile spondylium. At first this appears to be a radical departure from the normal condition of the species, but specimens can be found in all degrees of transition from straight and nonconvergent to strongly bowed and fused. Some large shells with straight dental plates (normal for the species) appear to have the plates meeting and fusing near the beak, but diverging in their forward growth and distinctly separate at their anterior terminations. On the other hand, most small specimens have the plates distinctly separate too. Therefore, the apparent fusing of the plates may be the result of deposition of adventitious shell material between the plates as the shell grew.

### *Meekella occidentalis* (Newberry)

PLATE 117: FIGURES 1-4, 9-13

*Streptorhynchus occidentalis* Newberry, 1861:126, pl. 1: figs. 5, 5a.

*Meekella occidentalis* (Newberry) Hall and Clarke, 1892: pl. 11B: figs. 18, 19.—McKee, 1938:222, pl. 43: figs. 2, 3.

*Streptorhynchus pyramidalis* Newberry, 1861:126, pl. 2: figs. 11-13.

*Meekella pyramidalis* (Newberry) Hall and Clarke, 1892: 266.—McKee, 1938:223, pl. 43: figs. 4-6.

*Meekella grandis* R. E. King, 1931:54, pl. 6: figs. 5-7.

Since this species has been described by Newberry and King under different names, the salient features of the species thus have been detailed and need not be repeated here. The species is rare in the Glass Mountains. The end members of some variants of *M. calathica* resemble *M. occidentalis*, but we have concluded that the two are not the same. More specimens from the Grand Canyon, and especially a series of all stages of growth, will be necessary to establish a firm relationship.

## MEASUREMENTS (in mm).—

|                  | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 768         |                            |                             |                  |                |                     |           |
| 92468 (holotype) | 43.7                       | ?                           | 47.0*            | 36.6*          | 11.0?               | 7.7       |
| USNM 768a        |                            |                             |                  |                |                     |           |
| 92469            | 47.8                       | 42.4                        | 57.0?            | 35.0?          | 16.7                | 22.0?     |
| King 174         |                            |                             |                  |                |                     |           |
| YPM 10589        | 56.4                       | 54.5                        | 67.2             | 37.9           | 19.6                | 37.8      |

STRATIGRAPHIC OCCURRENCE.—Kaibab Formation (Beta Member), Cathedral Mountain Formation.

LOCALITIES.—Kaibab: USNM 768, 768a; Cathedral Mountain: R. E. King 174, USNM 702, 726y.

TYPES.—Holotype: USNM 92468; paratype: 92469. Holotype of *Meekella grandis* R. E. King: YPM 10589.

DISCUSSION.—Under the name *M. occidentalis* we are combining Newberry's species *Streptorhynchus occidentalis* and *S. pyramidalis* and *M. grandis* R. E. King. All of these species are large and generally pauciplicate. Unfortunately, the type specimens of the first and last species are poor, and the type of *S. pyramidalis* appears to be lost. McKee (1938:224), who discusses these species, regards *S. occidentalis* to be a flattened *S. pyramidalis* because he was unable to find any specimens like the former in the Grand Canyon. He did, however, find specimens identifiable as *S. pyramidalis*, which showed a clear relationship to *S. occidentalis*. It is thus probable that Newberry's two species are synonymous. Schuchert (1897:264) expressed the view that "*M. occidentalis* Newberry . . . may prove to be but a large individual of *M. pyramidalis*."

Although *S. pyramidalis* has page preference, we have selected *S. occidentalis* for the specific name because the type specimens of this species are preserved, whereas those of *S. pyramidalis* are not available. Inasmuch as the two appear to be the same, the one can serve as well as the other. The holotype of *S. occidentalis* is the inner filling of a pedicle valve broken on one side. It has 12 costae, one of which is obscure. The dental plates as shown by their impression on the internal cast are convergent ventrally and anteriorly. These features and the convergent dental plates can be seen on a second specimen, a paratype.

Some uncertainty exists as to whether or not the complete specimen (USNM 92469) is actually a paratype. The specimen was not figured or re-

ferred to by Newberry, but Hall and Clarke (1892:266) refer to the two specimens of *M. occidentalis* as the "original specimens of the latter species." It may be assumed, therefore, that Newberry included the two in his species but that he only figured the holotype. Newberry's label, preserved with the paratype, indicates the specimen to be a "type." The paratype has a strong resemblance to *M. grandis* R. E. King.

King's type specimen of *M. grandis* is the largest specimen of the species complex here under discussion. It is slightly flattened, the beak region of the pedicle valve having been squeezed down onto the brachial valve and somewhat distorted, the distortion enhancing the resemblance to the paratype of *M. occidentalis*. The L/W ratio of the brachial valve is 0.8 and the costae number 14 on one valve and 15 on the other. The characteristic bifurcation of one or more costae can be seen on both valves.

*Meekella prionota*, new species

PLATE 99: FIGURES 1-39; PLATE 124: FIGURES 21-25

*Meekella striatocostata* (Cox) R. E. King, 1931:56, pl. 7: fig. 9 [not *M. striatocostata* (Cox) of authors].

Shell small to moderate size, biconvex, shallow conical; outline transverse, semicircular to subelliptical; hinge straight, width fairly constant between 0.55 and 0.75 width of shell, slightly auriculate at ends. Plications coarse, rounded, strong, numbering 6 to 14, with 9 and 10 most frequent, usually regular and undistorted, beginning about 6 mm from beak, some shells with 1 or 2 bifurcating. Costellae strong, parallel to plications except near margins of mature shells there converging toward crests of plications and increasing in number by intercalation in troughs. Growth lines faint, conspicuous only near margins; commissure coarsely plicate and minutely serrate.



Pedicle valve beak moderately sharp, often slightly twisted; fold obscure, low; interarea normally short and wide (about half as high as wide) except in unusually attenuate shells, longitudinally concave, meeting plane of commissure at obtuse angle; pseudodeltidium less than half but more than one-third hinge width, bisected by narrow, low, gently rounded ridge.

Brachial valve moderately to strongly convex, maximum convexity near beginning of plications, beak projecting posteriorly slightly overhanging hinge; plications equal in number and strength to those on pedicle valve. Median region sulcate, sulcus shallow, most conspicuous at midvalve.

Pedicle valve interior with sharp, moderately

strong hinge teeth, extending posteriorly as convergent dental ridges toward beak, about half way to apex, curving toward floor of valve as slightly convergent dental plates, thence continuing anteriorly along valve floor, normally nearly parallel to one another, rarely meeting and fusing along floor. Muscle marks between plates very weak.

Brachial valve interior with wide, blunt, slightly curved cardinal process, with short bifurcation of free end, each branch longitudinally slit for short distance and minutely serrate within slit. Promontorium narrow; dentifers thin, fused to elongated erismata; fulcral plates small. Muscle marks obscure, consisting of faint longitudinal striae, divided by low myophragm.

MEASUREMENTS (in mm).—

|                   | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|-------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701-1        |                            |                             |                  |                |                     |           |
| 150539a           | 6.0                        | 5.0                         | 6.0              | 4.4            | 1.9                 | 3.6       |
| 150539b           | 8.8                        | 7.0                         | 7.7              | 6.0            | 4.3                 | 5.8       |
| 150539c           | 10.6                       | 9.7                         | 11.7             | 7.5            | 3.9                 | 8.8       |
| 150539d           | 14.5                       | 12.1                        | 14.6             | 9.4            | 7.0                 | 11.9      |
| 150539e           | 17.0                       | 15.3                        | 18.6             | 13.0           | 9.4                 | 15.0      |
| 150539f           | 20.6                       | 16.8                        | 20.8             | 12.6           | 10.0                | 15.0      |
| 150539g           | 25.4                       | 18.3                        | 22.0             | 16.4           | 8.7                 | 17.0      |
| USNM 701d         |                            |                             |                  |                |                     |           |
| 150537a           | 25.9                       | 21.8                        | 24.2             | 13.6           | 7.4                 | 19.8      |
| 150537b           | 25.6                       | 22.8                        | 25.3             | 16.0           | 6.4                 | 22.7      |
| 150537c           | 27.2                       | 26.1                        | 30.0             | 18.2           | 9.7                 | 22.0      |
| 150537d           | 34.5                       | 29.5                        | 34.0             | 22.6           | 10.0                | 24.9      |
| USNM 701k         |                            |                             |                  |                |                     |           |
| 150616            | 28.4                       | 26.7                        | 32.3             | 20.9           | 12.7                | 25.6      |
| USNM 727e         |                            |                             |                  |                |                     |           |
| 153339 (holotype) | 22.5                       | 22.8                        | 27.6             | 16.4           | 11.0                | 21.5      |

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 4-14 of P. B. King), Lenox Hills Formation, Cibolo Formation.

LOCALITIES.—Gaptank: USNM 700a, 700g; *Uddenites*: 701p, 701v, 702n, 703x, 713o; Neal Ranch: 701, 701a, 701a<sup>3</sup>, 701c, 701d, 701h, 701k, 701-l, 713h, 721g, 727d, 727e; Lenox Hills: 705, 705k, 707m; Cibolo: 728-l.

DIAGNOSIS.—Medium-sized *Meekella* with fairly well-marked sulcus on brachial valve.

TYPES.—Holotype: USNM 153339; figured paratypes: 150616a, b, 153533a-k; measured paratypes: 150537a-d, 150539a-g.

COMPARISON.—*Meekella prionota* is characterized

by its small size and few strong, rounded plications, relatively low interarea, and shallow conical pedicle valve beak, strong costellae, slight auriculation of hinge ends, brachial valve sulcus, and well-separated dental plates. Its shape is fairly regular and undistorted. It may be distinguished from *M. magnifica*, new species, which also occurs in the Neal Ranch, by most of the above features (excepting only the strong costellae, and the shallow pedicle valve beak that occurs in *M. magnifica* but is not typical).

It may be distinguished from *M. occidentalis* (Newberry) by its stronger costellae, normally fewer plications, and narrower range in number of plications, its less auriculate hinge ends, and smaller

maximum and average size as *M. skenoides* Girty, but it differs in its fewer and blunter plications, lower interarea, and shallower pedicle beak, stronger costellae and normally backward sloping interarea. It differs from *M. attenuata* Girty and *M. caperata*, new species, by its fewer and much coarser plications, smaller size, less attenuate and less transverse shape.

DISCUSSION.—*Meekella prionota* is one of the least variable species of *Meekella* in the Glass Mountains. It is rare, occurring abundantly at only one locality and rarely at a few other localities in Wolfcampian formations. Its greatest variation is its shape, a condition normal for species of *Meekella*. Its size is remarkably consistent, as is the number and shape of its plications. The plications may begin farther forward on some specimens than on others, and a few may begin so far forward that the shell may resemble an individual of *M. magnifica* R. E. King.

This is the species that King (1931:56) equated with *M. striatocostata* (Cox), the common Pennsylvanian "species." *Meekella prionota* differs from Pennsylvanian specimens, called "*M. striatocostata* (Cox)" by its smaller size, stronger costellae, fewer and less variable number of plications, and lower interarea. Most Pennsylvanian species of *Meekella* are referred to *M. striatocostata*. This species name has little meaning, leading to the belief that several species are now masquerading under that name.

### *Meekella skenoides* Girty

PLATE 99: FIGURES 40, 41; PLATE 101: FIGURES 9–13; PLATE 104: FIGURES 1–10; PLATE 108: FIGURES 6–10; PLATE 115: FIGURES 1–32; PLATE 116: FIGURES 1–8

*Meekella skenoides* Girty, 1909:206, pl. 30: figs. 8–9.—R. E. King, 1931:56, pl. 7: figs. 6–8.—Newell et al., 1953: pl. 21: fig. 1.

*Meekella difficilis* Girty, 1909:207, pl. 30: fig. 10. [Not *M. difficilis* R. E. King = *M. calathica*, new species.]

Shell small to moderately large, biconvex, shallow to deeply conical; outline transversely subelliptical, to nearly semicircular; hinge straight, between 0.5 and 0.75 maximum width, often slightly auriculate. Plications fine to moderately coarse, moderately

strong to strong, normally rounded on crests, but often sharp, numbering 7 to 20, averaging 11 to 14, rarely bifurcating, beginning 3 to 15 mm anterior to beak, averaging about 6 mm. Costellae moderately strong near beaks, becoming weaker anteriorly, growing parallel to plications, converging over their crests only near margins of large shells; growth lines faint, conspicuous only near shell margins. Commissure coarsely to finely plicate, minutely serrate where costellae terminate.

Pedicle valve beak sharp unless deformed by attachment surface, interarea long (normally nearly as long as wide, rarely longer, rarely more than twice as wide as long), flat to slightly concave, in adults meeting plane of commissure at right angle; pseudodeltidium expanding dorsally, sides parallel to sides of interarea in all but shells with exceptionally short and wide interareas, edges obscure, width one-third to slightly more than one-half total hinge width, bisected by low rounded narrow ridge.

Brachial valve moderately convex, maximum convexity near beak, projecting only slightly posterior to hinge.

Pedicle valve interior with strong symmetrical teeth extending posteriorly as convergent dental ridges about half way to apex, then expanding and curving to valve floor with slight convergence, and extending anteriorly along floor, slightly divergent, parallel, or more rarely meeting at floor of valve. Muscle marks on inner sides of plates parallel to anterior edges of plates.

Brachial valve hinge surface shallow, concave; cardinal process strong, moderately to strongly curved, keeled near hinge but bifurcate at free end, each branch longitudinally slit and finely serrate, on some shells slit penetrating branch, thus making end of process quadriramous. Promontorium slightly concave both longitudinally and transversely, extending along cardinal process for more than half length, widening toward proximal end, contracting abruptly immediately anterior to hinge sockets; dentifers fused to cardinal process by gusset; erismata outlining muscle area in deep umbonal arch. Floor of muscle area uneven, bisected by low myophragm; muscle marks obscure, consisting of longitudinal striae on floor of muscle area and on bases of erismata.

## MEASUREMENTS (in mm).—

|                   | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|-------------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 706e         |                                     |                                      |                          |                        |                             |                  |
| 150560a           | 26.4                                | 26.4                                 | 34.2                     | 21.5                   | 14.6                        | 27.8             |
| 150560b           | 31.5                                | ?                                    | 38.7                     | 21.8                   | 19.4                        | 20.0             |
| 150560c           | ?                                   | 33.8                                 | 44.2                     | 20.8                   | ?                           | 18.6             |
| 150560d           | 34.3                                | ?                                    | 48.0                     | 29.5                   | 19.2                        | 23.8             |
| 150560e           | ?                                   | 44.0                                 | 51.6                     | 24.0                   | ?                           | 20.0+            |
| USNM 728          |                                     |                                      |                          |                        |                             |                  |
| 150554a           | 38.5                                | ?                                    | 45.0                     | 24.1                   | 17.0                        | 20.7             |
| 150554b           | ?                                   | 28.7                                 | 34.0                     | 18.5                   | ?                           | 14.0             |
| 150554c           | 20.6                                | 20.6                                 | 22.6                     | 16.3                   | 11.5                        | 19.6             |
| 150554d           | 17.8                                | 17.0                                 | 21.4                     | 15.3                   | 8.5                         | 15.2             |
| 150554e           | 12.3                                | 10.5                                 | 15.6                     | 12.0                   | 6.4                         | 10.4             |
| 150554f           | 11.9                                | 11.6                                 | 13.6                     | 9.7                    | 6.2                         | 10.3             |
| 150554g           | 11.5                                | 11.0                                 | 12.7                     | 8.0                    | 6.1                         | 10.6             |
| King 192          |                                     |                                      |                          |                        |                             |                  |
| YPM 11000         | 23.4                                | 22.8                                 | 28.2                     | 19.6                   | 12.0                        | 22.8             |
| USNM 706c         |                                     |                                      |                          |                        |                             |                  |
| 150550a           | 4.6                                 | 4.4                                  | 4.5                      | 3.7                    | 3.3                         | 3.9              |
| 150550b           | 7.5                                 | 5.6                                  | 5.9                      | 3.7                    | 3.6                         | 4.6              |
| 150550c           | 7.8                                 | 7.6                                  | 8.2                      | 5.7                    | 6.0                         | 8.4              |
| 150550d           | 10.4                                | 9.7                                  | 11.4                     | 8.8                    | 6.3                         | 9.8              |
| 150550e           | 11.4                                | 11.2                                 | 13.2                     | 7.8                    | 11.7                        | 15.2             |
| 150550f           | 15.5                                | 14.0                                 | 16.9                     | 8.2                    | 5.5                         | 13.9             |
| 150550g           | 16.5                                | 14.9                                 | 19.0                     | 12.9                   | 6.0                         | 15.0             |
| 150550h           | 18.2                                | 16.5                                 | 21.0                     | 12.3                   | 10.0                        | 20.0             |
| 150550i           | 5.4                                 | ?                                    | 24.5                     | 19.6                   | 18.0                        | 17.8             |
| USGS 7417         |                                     |                                      |                          |                        |                             |                  |
| 150949a           | 23.7                                | 23.7                                 | 28.4                     | 15.8                   | 22.6+                       | 30.8             |
| USGS 3763 (green) |                                     |                                      |                          |                        |                             |                  |
| 118508 (holotype) | 11.6                                | 11.3                                 | 12.7                     | 7.0                    | 8.0+                        | 12.0             |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Road Canyon Formation, Word Formation (China Tank, Willis Ranch, and Appel Ranch members, and lens between the last two), Bell Canyon Formation (Hegler, McCombs, and Pinery members), Capitan Formation, Carlsbad Formation?, San Andres Formation.

LOCALITIES.—Getaway: AMNH 28, 512, 519, 496, 585, 600, 652, Moore 31, USNM 728, 730, 732; Road Canyon: USNM 706f, 707e, 713, 716xa, 732i; Word: USNM 731m, 731p, 731u, 732c, 732s; China Tank: USNM 706a, 706c, 706z, 718d, 726r, 726s, 733q, ?USGS 3763; Willis Ranch: AMNH 505, USNM 706, 706e, 723t, 724u; Appel Ranch: USNM 704, 706d, 714o, 715i, 716v, 719z, 722t, 727j; Hegler: AMNH 635; Pinery: AMNH 398; 537; McCombs: AMNH 409; Capitan: USGS 7417 (blue); Carlsbad?: AMNH 417; San Andres: B-188-8.

DIAGNOSIS.—Medium-sized to large *Meekella* with strong angular plications averaging 12 in number.

TYPES.—Holotype: USNM 118508; paratype: 118509; figured hypotypes: 150544e, 150554b, c, e, 150559a-d, 150820, 150949a, 153518, 153519, 153534a-c, 153537, 153538, 153542a-k, 155127; measured hypotypes: 150550a-i, 150554a-g, 150560a-e, 150949a, YPM 11000.

COMPARISON.—*Meekella skenoides* is characterized by its moderate size (only rare individuals attain a width of 50 mm), normally sharp and fairly regular plications that start far backward on the beak, slight or missing auriculation of hinge extremities, commonly separate dental plates, and proportionately high interarea.

Its sharp and coarse plications, much smaller maximum size, and more regular shape distinguish it from *M. magnifica*, new species. Its less promi-

nent auriculation, smaller size, flatter and higher interarea, and parallel costellae separate it from *M. occidentalis* (Newberry). *Meekella skenoides* may be distinguished from *M. prionota*, by its finer and sharper plication, slightly auriculate hinge, lack of sulcus in brachial valve, more regular shape, normally right angle between interarea and plane of commissure, and proportionately higher interarea.

Its stronger costellae, fewer plications, less attenuate pedicle beak, and shallower promontorium distinguish *M. skenoides* from *Niviconia globosa* (King). It differs from *M. caperata* in its fewer and coarser plications, less transverse outline, and less attenuate pedicle beak.

DISCUSSION.—Girty (1909:206–207) described two species of *Meekella* collected in 1899 by R. T. Hill from “Comanche Canyon, Glass Mountains, 17 miles northeast of Marathon, Texas.” The location of “Comanche Canyon” may be the valley from Hess Ranch to Split Tank, and the specimens are thought to have been collected from the Word Formation (Willis Ranch Member). Although the holotypes of *Meekella skenoides* Girty and *M. difficilis* Girty both have the same locality number, there is little assurance that they were collected at a single precise locality or were closely associated in the rock. All that is certain is that they were collected in “Comanche Canyon.” We compared these holotypes with numerous lots from the upper Cathedral Mountain, Road Canyon, and Word formations. They proved completely unlike the Cathedral Mountain specimens, but individuals almost identical to them could be seen in collections

from the Word Formation (Willis Ranch Member). King (1931:53, 56), however, considered them so remotely associated that he used, erroneously we think, the name “*M. difficilis* Girty” for a species that occurs in the Cathedral Mountain Formation, but he identified *M. skenoides* Girty from the Word.

The holotypes of *Meekella skenoides* Girty and *M. difficilis* Girty are different from one another, but these differences are the result of growth and are not specific differences. The holotype of *M. skenoides* is a juvenile, and that of *M. difficilis* an average-size adult; the two are alike in all significant features. Study of our large collections has shown that both of these holotypes fall well within the limits of variation of a single species of *Meekella*. Inasmuch as “*M. skenoides* Girty” has already been used by R. E. King in essentially the same sense as we use it, this is the name we prefer for the species.

Although we regard the specimens discussed in this section as belonging to a single species, an interesting deviation occurs in specimens coming from the prolific locality USNM 706e. These have a slightly larger number of plications than those from the other limestone members of the Word and from the Getaway Member of the Cherry Canyon Formation.

The plications on 100 specimens from USNM 706c were counted, and it was found that the most frequent number in the sample was 11 plications.

The following table illustrates the results of the count (USNM 706c):

| plications          | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---------------------|---|---|---|----|----|----|----|----|----|----|
| number of specimens | 2 | 4 | 8 | 13 | 33 | 20 | 9  | 7  | 4  | 0  |

From inspection it appeared that the number of plications on *M. skenoides* from USNM 706e was greater than the above, and the plications finer. A

count on 100 specimens from USNM 706e gave the following results:

| plications          | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---------------------|---|---|----|----|----|----|----|----|----|----|----|----|
| number of specimens | 1 | 2 | 6  | 10 | 19 | 20 | 21 | 7  | 8  | 3  | 2  | 1  |

When combined, the data from these two counts produce a fairly smooth normal population curve. The difference in numbers of plications in the two samples is so slight and other features so consistently similar that there is no doubt only one species is involved; however, the difference in num-

bers of plications in specimens from USNM 706e is real and is obvious enough to be recognized by inspection, even without counting, if large samples are available. The average number of plications on specimens from USNM 706e is 13; consequently, no significant difference appears.

Furthermore, separation on the basis of the number of plications appears completely artificial when applied to localities other than USNM 706e. Inasmuch as Girty's types of *M. skenoides* and *difficilis* have 12 plications and the former appears to be a young form of the latter, it seems best at this time to recognize one species only, *Meekella skenoides*.

### *Meekella texana* R. E. King

PLATE 118: FIGURES 1-7

*Meekella irregularis texana* R. E. King, 1931:55, pl. 6: figs. 2-4 (not fig. 1).

This "variety" of Schellwien's species (*M. irregularis*) is represented by a type lot of four incomplete specimens, three of which are only equivocally related to the holotype. The first is the specimen represented by King's figure 1, a more coarsely plicated specimen than the others, which, as may be seen in the figure, bears the number "965," but no number is given in the plate legend or text to show to what institution the specimen belongs. The rest of the specimens in the type lot are numbered serially from 10966 to 10968. It is evident therefore that the individual depicted by figure 1 belongs in the series with the number 10965. In any event, the specimen is so unlike the others that it is excluded from this association. Moreover, it comes from the Decie Ranch Member of the Skinner Ranch Formation, and, if it is from the Wolfcamp Series, probably it is from the Lenox Hills Formation, whereas the other specimens are from below it.

The specimen designated as holotype is from the Gaptank Formation, (*Uddenites*-bearing Shale Member) east of Wolf Camp, whereas YPM 10968 is from the same member at Wolf Camp. Neither of these specimens has very strong characters because they are exfoliated and incomplete. The latter could be a variant of the former, but it is impossible to tell because it varies in ornament as well as shape. The holotype presents a more attenuated form with the plications not reaching the beak.

The fourth specimen, YPM 10967, is a brachial valve that comes from bed 13 of the Gaptank Formation in hill 4572 northeast of the Wolf Camp Hills. Its assignment to the *Uddenites*-bearing Shale Member is doubtful because this member is not definitely known at this place. This specimen

is wider than long, transversely elliptical in outline, and has an even, gently convex profile in both lateral and anterior directions. Fifteen costae were counted; the posterolateral extremities are smooth or the specimen too exfoliated to see them. A fairly strong myophragm is present, and the supporting plates are strong and diverge at an angle of 50°. This specimen is nearer the holotype than to the others, but it is not possible to tell if they are the same. The holotype of this "variety," thus, is the only specimen left to represent it.

MEASUREMENTS (in mm).—Holotype: length 17.3, maximum width 24.7, hinge width 16.6?, interarea length 15.5+, thickness 23.4+.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member); Lenox Hills Formation (=Neal Ranch of Ross).

LOCALITIES.—Gaptank: ?R. E. King 95, USNM 700g, 703o, 705q, 708p; *Uddenites*: R. E. King 88s, 199, USNM 701e, 701f, 701q, 702j, 702k, 702n, 702q, 703-1, 703c, 713b; Lenox Hills: USNM 715b.

TYPES.—Holotype: YPM 10966; figured paratypes: YPM 10965, 10967, 10968.

DISCUSSION.—King's variety differs from *M. irregularis* Schellwien, according to King, in having "a proportionately shorter hinge-line and wider deltidium." Comparison with other species from the Glass Mountains is difficult because of the difference of preservation between the silicified and exfoliated specimens. King's variety is not common in the *Uddenites*-bearing Shale Member and good specimens are difficult to obtain. We thought at first that a strong resemblance existed with *M. magnifica*, new species, because some unquestionable specimens of that species, have been taken from this zone. But the type specimens of *M. irregularis texana* do not give sufficient information on the interior and details of the ornament. Furthermore, the brachial valve (YPM 10967) is unusually low in convexity for our Wolfcampian species. In view of the difficulties and uncertainties, we have not used King's name for the common Neal Ranch species.

### Genus *Niviconia*, new genus

[Latin *nivis* (snow) + *conus* (cone)]

Meekelloid; pedicle valve deeply conical; brachial valve strongly convex; costae numerous (15-30),



simple, angular, rather low, beginning at beaks; costellae very fine and weak; interarea long, narrow, pseudodeltidium proportionately wide; monticulus high, thin.

Pedicle valve interior with dental plates moderately receding below dental ridges, converging but just not meeting on valve floor. Brachial valve interior with exceedingly long cardinal process curving posteroventrally, deeply bifurcate, each prong slit deeply and serrate; promontorium very wide near hinge, narrowing anteriorly, producing deep trough along each side of process and along erismata; sockets deep; erismata very long, extending along sides of muscle area on valve floor; dentifers projecting free beyond wide gussets; myophragm low or absent.

TYPE-SPECIES.—*Meekella globosa* R. E. King (1931:54, pl. 5: figs. 10–12c; pl. 32: fig. 8).

DIAGNOSIS.—Strongly convex *Meekella* with numerous low and even costae, nearly convergent dental plates, and a very long and strong cardinal process that is clearly differentiated into its component parts, and is braced by unusually long erismata.

COMPARISON.—In some features this genus might be considered intermediate between *Meekella* and *Geyerella*. Its nonconjunct dental plates ally it to *Meekella*, but the fact that they approach closer than normal in *Meekella* suggests *Geyerella*. The costation suggests *Geyerella* to some extent, but actually it is so distinctive as to make the genus recog-

nizeable on that criterion alone without recourse to internal details. The most distinctive feature, however, is the very long cardinal process that projects along the inside of the pedicle valve interarea for nearly its entire length.

DISCUSSION.—Only two species of *Niviconia* occur in the Glass Mountains, the type, *N. globosa* (King), and *N. abrupta*, new species. An undescribed species from the Cutoff Shale Member of the Bone Spring Limestone is present in the United States Geological Survey collections, mentioned by Girty (in P. B. King, 1948:24; locality USGS 7666).

### *Niviconia abrupta*, new species

PLATE 118: FIGURES 22–48

This species is closely related to *Niviconia globosa* (R. E. King), as it has the same narrow angular costae and the auriculate cardinal extremities. It differs in not attaining the large size of that species and in having a much shorter beak. The differences are shown most clearly in the young of *N. abrupta* when compared with those of *N. globosa*. The former are rounded shells with a short interarea, whereas the young of *N. globosa* are greatly elongated. Young adults of *N. globosa* may suggest *N. abrupta*, but their ventral beaks are always much more elongated.

#### MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | hinge<br>width | midwidth | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|----------------|----------|---------------------|-----------|
| 153540b            | 16.2                       | 17.0                        | 12.9           | 20.6     | 9.8                 | 17.8      |
| 150512d            | 12.3                       | 12.3                        | 11.0           | 13.8     | 8.2                 | 13.6      |
| 150512e            | 14.2                       | 14.1                        | 12.5           | 17.8     | 9.3                 | 16.5      |
| 150512f (holotype) | 27.9                       | 26.6                        | 19.0           | 31.7     | 15.0                | 27.7      |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (upper).

LOCALITY.—USNM 702a.

DIAGNOSIS.—Like *N. globosa* but small and with shorter interarea.

TYPES.—Holotype: USNM 150512f; figured paratypes: 150512e, f, 153540a–e; measured paratypes: 153512d, e, 153540b; unfigured paratypes 150512a–c, 153540f.

DISCUSSION.—This species is stratigraphically

younger than *N. globosa*, which occurs in the lower part of the Cathedral Mountain Formation.

### *Niviconia globosa* (R. E. King)

PLATE 30: FIGURE 1; PLATE 109: FIGURES 1–44; PLATE 110: FIGURES 1–22; PLATE 114: FIGURES 1–10

*Meekella globosa* R. E. King, 1931:54, pl. 5: figs. 10–12c, pl. 32: fig. 8.

Large, strongly biconvex with swollen brachial valve and deeply conical pedicle valve; outline transversely subelliptical to subtrigonal. Hinge extremities slightly auriculate, hinge one-half to three-fourths shell width. Plications angular, comparatively fine but strong, numbering 16 to 29, average about 22, normally straight and even, only rarely bifurcating, extending on to umbones; plications in juveniles resembling costellae. Costellae very fine and weak, visible only on unplicated flanks of valves just anterior to interarea; growth lines weak, most prominent near margins. Anterior commissure rectimarginate, serrate, each serration itself minutely serrated.

Pedicle valve beak attenuate, sharp, often twisted; interarea transversely flat, longitudinally concave, narrow, normally about as long as wide, meeting the plane of commissure at obtuse angle in immature shells, nearly at a right angle in mature specimens, pseudodeltidium about one-third as wide as interarea, transversely flat near beak, becoming transversely concave and sunken dorsally, bisected by thin, fairly high median monticulus. Lateral profile moderately convex; anterior profile fairly strongly and narrowly convex.

Brachial valve lidlike, with strong umbo overhanging pedicle interarea; plications equaling average number and strength to those of pedicle valve. Lateral profile strongly convex, and lateral profile moderately domed. Umbonal region swollen, anteromedian region flattened.

Pedicle valve interior with sharp, short, and weak

teeth, extending for short distance posteriorly as convergent dental ridges beneath interarea, abruptly widening into thin ventrally and anteriorly convergent dental plates, normally remaining slightly separated along valve floor, but converging and nearly meeting in some specimens. Muscle marks weak, consisting of striae on inner surfaces of dental plates.

Brachial valve hinge surface concave, shallow, forming short interarea; cardinal process long, strongly curved, extending anteriorly near hinge, then bending ventrally; free and widely bifurcate, each prong longitudinally and deeply slit along posterior surface, the slits containing minute serrations; prongs converging toward hinge, uniting into single high ridge. Promontorium wide near hinge, narrowing along length of process, slanting medially, making a deep trough along each side of process and along erismata. Sockets deep, semicircular, open on side away from process, other side and bottom formed by fulcral plates. Dentifers fused to cardinal process by gusset, the free ends projecting anteroventrally below cardinal process. Erismata diverging to form umbonal arch, bounding posterior limits of muscle area, and extending slightly forward along floor of valve for about one-fourth valve length. Muscle area bilobed, not appreciably thickened, with plications of exterior only slightly obscured by callus within area; muscle marks faint, on valve floor, and on inner bases of dentifer supports; myophragm low when present.

#### MEASUREMENTS (in mm).—

|            | <i>pedicle<br/>valve<br/>length</i> | <i>brachial<br/>valve<br/>length</i> | <i>maximum<br/>width</i> | <i>hinge<br/>width</i> | <i>interarea<br/>length</i> | <i>thickness</i> |
|------------|-------------------------------------|--------------------------------------|--------------------------|------------------------|-----------------------------|------------------|
| USNM 702a  |                                     |                                      |                          |                        |                             |                  |
| 150512a    | 5.3                                 | 5.0                                  | 6.4                      | 5.0                    | 3.7                         | 5.3              |
| 150512b    | 6.8                                 | 6.7                                  | 8.5                      | 5.9                    | 4.8                         | 7.4              |
| 150512c    | 12.0                                | 11.5                                 | 14.0                     | 8.0                    | 6.4                         | 11.5             |
| 150512d    | 13.0                                | 12.2                                 | 14.9                     | 10.0                   | 6.9                         | 13.7             |
| 150512e    | 14.0                                | 14.0                                 | 17.9                     | 13.0                   | 8.8                         | 15.5             |
| 150512f    | 29.1                                | 27.0                                 | 31.5                     | 18.5                   | 16.7                        | 27.0             |
| USNM 702b  |                                     |                                      |                          |                        |                             |                  |
| 150511a    | 3.0                                 | 3.0                                  | 4.0                      | 3.0                    | 2.2                         | 2.9              |
| 150511b    | 19.4                                | 16.5                                 | 19.6                     | 12.6                   | 14.0                        | 18.9             |
| USNM 702un |                                     |                                      |                          |                        |                             |                  |
| 150517a    | 23.8                                | 19.6                                 | 23.2                     | 15.5                   | 19.6                        | 28.0             |
| 150517b    | 39.0                                | 32.7                                 | 39.0                     | 22.8                   | 23.8                        | 30.2             |
| 150517c    | 50.6                                | 39.4                                 | 46.1                     | 29.4                   | 25.5                        | 40.0             |

incorrectly  
fig 25  
N. abrupta  
(pl. 118)

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (*Institella* zone, *Eolyttonia* zone), Road Canyon Formation.

LOCALITIES.—*Institella* zone: AMNH 500A–C, F–H, J, L–N, USNM 702, 702b, 702ent, 702inst, 702 (low), 702un, 703b, 703bs, 708u, 711q, 726x; *Eolyttonia* zone: AMNH 504, USNM 702a, 703a<sup>1</sup>; Road Canyon: AMNH 503, USNM 703a, 703c.

DIAGNOSIS.—Large *Niviconia* with elongate pedicle valve and narrow, numerous angular plications.

TYPES.—Holotype: YPM 10944; figured paratype: YPM 10945, T10609; figured hypotypes: USNM 150516b–n, 150517a, 153048, 153532, 153533a–c, e, g–i; unfigured hypotypes: USNM 150516a, 150517b, c, 153533d, f; measured hypotypes: USNM 150512a–f, 150511a, b, 150517a–c.

COMPARISON.—*Niviconia globosa* is characterized by its numerous and fine, although strong, angular plications that extend to the beak on each valve, its attenuate pedicle beak, strongly convex brachial valve, slightly auriculate hinge, dorsally sunken pseudodeltidium, and especially by the peculiar fusion of promontoria to the cardinal process, which itself is exceptionally long and strongly curved. The socket plates are fused more loosely to the process than in other species, and they slant toward the process so as to form a trough on each side of it. This loose construction of the cardinal process complex makes apparent the juncture of socket plates with dentifers.

This species is closest in size and outline to *Meekella calathica* from which it differs in its more attenuate pedicle beak, less auriculate hinge extremities, more convex brachial valve, finer and more numerous plications that extend to the apex, finer costellae, and peculiar cardinal process. The numerous, fine plications extending to the beaks and the odd attachment of the socket plates to the cardinal process and brachiophores distinguish this species from *M. texana* King, *M. prionota*, new species, and *M. grandis* King. Although the plications on some specimens of *M. skenoides* Girty reach nearly to the pedicle beak, its plications are fewer, its costellae coarser, and its maximum size much smaller than in *N. globosa*. Also its dental plates normally are more widely separated along the floor of the valve, and the socket plates are fused more solidly to the cardinal process. *Meekella caperata* has numerous fine plications and an at-

tenuate pedicle beak, and it attains a size similar to that of *N. globosa*. But its plications are not as strong or as angular and do not extend to the beaks as in *N. globosa*, its costellae are much coarser, and elements that attach to the cardinal process are more strongly constructed. *Niviconia abrupta* is like *N. globosa*, but it is smaller and has a much shorter pedicle valve.

DISCUSSION.—*Niviconia globosa* is not as highly variable as most species of *Meekella*. Its plications vary in number only between 16 and 29, and normally are straight and even, although they curve as the shell is twisted or is otherwise deformed. The pedicle beak normally is rather long and attenuate, not strongly curved and blunt as in King's (1931, pl. 5: figs. 12a–c) reconstruction.

The most remarkable and characteristic feature of this species is the manner of attachment of the dentifers and promontoria to the cardinal process. The dentifers project more strongly from the main body of the cardinal process than is typical in other species of the genus, and the promontoria are not so strongly fused to the process and dentifers. In addition, the promontoria slant steeply toward the process and form a pair of troughs, one running along each side of the process. The peculiar construction of the cardinal process complex makes most specimens of this species easily distinguishable from most specimens of other species; however, some individuals of *Meekella calathica* have similarly constructed processes, and some specimens of *N. globosa* have tighter fusion of the components than is typical of the species. Other features, such as number and coarseness of plications, location of beginning plications on the beaks, and fineness of costellation, distinguish specimens of these two species that may have similarly constructed cardinal process complexes.

### Genus *Geyerella* Schellwien, 1899

*Geyerella* Schellwien, 1900a:4.—Girty, 1909:203.—R. E. King, 1931:219.—Sarycheva, 1960:219.—Williams, et al., 1965: H405.

*Turriculum* De Gregorio, 1930:26.

Small to very large, conical, biconvex; outline strongly transverse to nearly circular; plications weak to strong, few or many, beginning at, or far forward of, beaks, regular or irregular, straight or bifurcating; costellae normally weak, variable in

strength, parallel to plications, crossing them, or converging toward their crests anteriorly.

Pedicle valve forming shallow or deep cone, commonly twisted or bent, deformed by attachment scars or by contact with foreign objects; interarea long and narrow, transversely flat, longitudinally concave or convex, meeting sides at wide angle; dental plates convergent meeting above valve floor, uniting with median septum to form Y-shaped spondylium.

Brachial valve moderately to strongly convex, with prominent swollen umbo and overhanging beak; interior with large cardinal process like that of *Meekella* with prominent promontorium and erismata narrowly to widely divergent into umbonal arch, outlining posterior of bilobed muscle area, which is divided by low myophragm.

TYPE-SPECIES.—*Geyerella gemmellaroi* Schellwien (1900a:12, pl. 1: figs. 7a, b).

COMPARISON.—*Geyerella* is characterized by the union of its dental plates with a median septum above the floor of the pedicle valve, forming a spondylium, and by its plicated shell. It differs from *Streptorhynchus* King, *Kiangsiella* Grabau and Chao, and *Tropidelasma* Cooper and Grant by the possession of dental plates and from all but *Kiangsiella* also by its plications. It differs from *Meekella* White and St. John and from *Sicelia* Merla by the juncture of the dental plates to form a spondylium and from the latter by its plications. It differs from *Ombonia* Caneva, which has a spondylium, by its plications and by the details of the cardinal process.

DISCUSSION.—Individuals belonging to species of *Geyerella* grew attached to the substrate by some part of the posteroventral surface of the pedicle valve. Frequently they grew in clusters, closely pressed against one another. This habit of growth caused great modification of the shells; they are deformed or indented at points of contact with the substrate or other shells, and they are commonly bent or twisted where growth was inhibited by the obstruction of foreign objects. This twisting of the pedicle valve is often a good distinguishing character of the genus. Such modifications of the shell produce great variation in the shape of individual shells, similar to that found in other directly attached forms.

Features that are relatively stable within the spe-

cies of *Geyerella* and that therefore characterize and distinguish the species are the maximum and average size, the twisting of the pedicle valve, the angle between the interarea and sides of the pedicle valve, the number, strength, coarseness and place of beginning of plications, the frequency of bifurcation of plications, the strength and course of costellation, and the convexity and prominence of the beak in the brachial valve. Variable characters that have no specific significance are the amount of distortion other than twisting, the outline of the shell, the proportional width of the hinge or interarea, the depth of the pedicle valve or the height of the interarea, the position of the juncture of dental plates, the forward extent of the extremities of the median septum of the brachiophore supports, the length or amount of bending or bifurcation of the cardinal process, and the manner of attachment of the dentifers and promontorium to the process.

A few specimens are silicified incompletely, and the two lamellae of the median septum can be seen to be separate. This supports Campbell's (1957:44) belief that "*Geyerella* was undoubtedly developed from *Meekella* by union of the dental lamellae on the floor of the valve"—an opinion shared by R. E. King (1931:57) and Stehli (1954:296).

### *Geyerella americana* Girty

PLATE 89: FIGURE 1; PLATE 125: FIGURES 1-4

*Geyerella americana* Girty, 1909:204, pl. 11: figs. 2-2b.

*Orthotetes distortus* Girty, 1909:201, pl. 10: figs. 9-9c.

*Orthotetes distortus* var. *campanulatus* Girty, 1909:202, pl. 10: figs. 10-10c.

The holotype of this species is badly damaged, exfoliated, and the left side is missing. The breakage is not all bad because the spondylium is revealed in detail and assures the identification of the genus. Girty speaks of a broad and convex pseudodeltidium being somewhat depressed below the surface of the interarea. This condition is brought about by the exfoliation of the shell. What the observer sees is an impression of the convex underside of the delthyrial cavity and the adjacent umbonal chamber. This accounts for the supposed convexity, because, on the interior, the pseudodeltidium will not be convex but will be flat as in *Meekella* and *Tropidelasma*. Very little more can be gleaned from Girty's type other than the fact

that part of the brachial valve is present and shows as an inverted V where the cardinal process has been broken. This indicates a narrow but long cardinal process that is corroborated by probable brachial valves newly discovered.

Large brachial valves almost certainly belonging to this species help to complete the picture of this poorly known *Geyerella*. In addition to the two complete specimens, fragmentary etched posterior parts of four brachial valves are also available. The best of the complete specimens is a silicified valve (USNM 150990) from the Lamar Limestone Member. It is 42.3 mm long and 52.8 mm wide and has a thickness of 20 mm. The umbonal region is narrowly convex, and the swelling extends to the midvalve, where it merges in the moderately convex anterior region. The umbonal slopes are steep. The hinge is very narrow, less than half the maximum width. The exterior is paucicostate; the umbonal region is unplicated, but the anterior two-thirds have about 30 narrowly angular bifurcating plications separated by troughs narrower than the plications.

The interior is provided with a large stout cardinal process extending almost at right angles to the lateral commissure plane and descending slightly anteriorly in a moderate curve. The myophore is forked and the dentifers small and supported by short, outwardly curved supporting plates (erismata), which are slightly concave anteriorly. The promontorium is small and poorly developed and is not extended distally to the brachiophore. The chilidial boss is bilobed in section, large and fairly long, but with an inconspicuous keel. The posterior of the umbonal chamber contains a fairly strong but low myophragm.

*Geyerella americana* is a large and distinctive species. It is not as large as *G. hessi*, is more strongly and numerously plicated, and has a narrower umbonal region; it is very rare. Beside the type, the USNM collection has only a few complete brachial valves.

*Orthotetes distortus* Girty and its variety, *O. d. campanulatus* Girty, are placed in the synonymy of *G. americana*. The species and variety appear to be young specimens. They have long spondylia, the trace of which can be seen where the shells are thin and exfoliated. The specimens are unplicated, which is normal for the young.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation, Bell Canyon Formation (Lamar Member).

LOCALITIES.—Capitan: USGS 2926 (green), AMNH 725; Lamar: AMNH L-2 (=AMNH 347), AMNH 384, USNM 725e, 728p, 728q, 738, 738b.

TYPES.—Holotype: USNM 118506; figured hypotypes: 150990, 153543.

### *Geyerella hessi*, new species

PLATE 89: FIGURES 2-4; PLATE 121: FIGURES 1-24; PLATE 122: FIGURES 1-10; PLATE 123: FIGURES 1-21; PLATE 124: FIGURES 14-20; PLATE 671: FIGURE 19

*Geyerella americana* R. E. King (not Girty), 1931:57, pl. 7: figs. 10-13.

Very large, biconvex, deeply conical, most somewhat distorted; outline transversely subelliptical to nearly circular; hinge up to 0.9 total shell width in smallest individuals, normally about half as wide as shell in all but smallest specimens, ends of hinge not auriculate but meeting sides of shell with distinct angularity. Plications strong, moderately coarse, sharp, irregular or slightly nodular, many bifurcating, numbering 10 to 30, averaging 20, beginning about 10 mm anterior to beak. Costellae fine, converging toward crests of plications only on moderately large to large shells; growth lines frequent and rather prominent, producing low nodules where they interrupt plications. Commissure coarsely plicate and minutely serrate for sieving incoming food currents. Pedicle valve deeply conical, with beak blunt to attenuate, normally distorted or bent by contact with attachment surface or other external objects; interarea narrow, transversely flat, longitudinally concave, meeting sides of valve with distinct change in slope, meeting plane of commissure at angle near 90°; pseudodeltidium occupying about one-third of total width of interarea at hinge, bisected by low rounded median ridge. Brachial valve moderately to strongly convex, with slightly to greatly overhanging beak.

Pedicle valve interior with strong, narrow hinge teeth, extending ventrally inside interarea as convergent dental ridges, curving toward floor of valve as dental plates, meeting and fusing into median septum above floor of valve, forming Y-shaped spondylium; median septum continuing short distance along floor. Muscle marks in spondylium as faint striae and low crenulations.

Brachial valve interior with strong curved cardi-



nal process, with short bifurcated free end, each branch longitudinally slit along posterior edge, and with minute serrations within each slit, branches meeting about midway to form shaft or proximal half of process. Promontorium narrow, thick, tapering distally, either at right angles or sloped toward process to form trough on each side of process, similar to that in *Niviconia globosa* (King); chilidial boss small; proximal ends of

socket ridges flexed to form fulcral plates; erismata diverging dorsally, meeting floor of valve in umbonal arch, outlining posterior of muscle area, extending anteriorly for short distance along floor of valve. Muscle area between erismata bilobed, bisected by low myophragm; muscle marks weak, consisting of longitudinal striae in muscle area and on bases of dentifer supports.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 707a          |                            |                             |                  |                |                     |           |
| 150975a            | 15.5                       | 10.0                        | 12.5             | 8.2            | 11.0                | 12.9      |
| 150975b            | 18.2                       | 16.0                        | 18.2             | 9.8            | 7.0                 | 16.8      |
| 150975c            | 27.3                       | 22.5                        | 25.9             | 12.0           | 11.0                | 21.9      |
| 150975d            | 27.6                       | 27.6                        | 30.0             | 14.6           | 14.6                | 28.9      |
| 150975e            | 38.8                       | 34.5                        | 38.0             | 22.3           | 23.0                | 39.0      |
| 150975f            | 41.0                       | 38.7                        | 43.0             | 24.5           | 39.6                | 52.8      |
| 150975g            | 44.4                       | 44.4                        | 51.0             | 23.0           | 38.5                | 53.0      |
| 150975h            | 49.0                       | 49.0                        | 48.0             | 25.7           | 51.8                | 77.3      |
| 150975i            | 59.5                       | 49.3                        | 60.5             | 31.0           | 27.7                | 58.6      |
| 150975j            | 63.0                       | 50.7                        | 68.2             | 41.7           | 44.6                | 72.0      |
| 152605a (holotype) | 55.0                       | 51.4                        | 53.3             | 33.3           | 38.0                | 66.0      |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Cibolo Formation.

LOCALITIES.—Decie Ranch: USNM 707a, 707w, 708q, 714t, 727u; Poplar Tank: 707h; Sullivan Peak: 704y, 707, 707x, 714y, 715f, 715h, 715j, 722-l, 722m, 726-l, 729-l, 733j; Skinner Ranch (lower): 705a, 711d, 712p, 714p, 716t; Skinner Ranch (upper): 710r; Cibolo: 738r.

DIAGNOSIS.—Very large *Geyerella* with an average of about 20 plications and usually a long twisted beak.

TYPES.—Holotype: USNM 152605a; figured paratypes: 147735a, 150974, 150975a, c, g, j, 150982a-c, 152605b, c, 153508a-i, 153544a, b.

COMPARISON.—*Geyerella hessi* is distinguished by its large size, moderately deep to very deep pedicle valve, numerous irregular and bifurcating plications that start near the beak, and distinct angle between the sides of the pedicle valve and the flat interarea. Its closest American relative is *G. americana* Girty (1909:207) from the Capitan Limestone of the Guadalupe Mountains, which differs in having a somewhat depressed interarea, more narrowly elongate rather than transverse outline, fainter

costellation, and perhaps a more marginally flared pedicle valve in the juvenile shell. This comparison is based on the poorly preserved holotype of *G. americana* and the associated juvenile shell that Girty (1909:202) called "*Orthotetes distortus* var. *campanulatus*." King (1931:57-58) recognized that *O. distortus* var. *campanulatus* was in fact a juvenile of *Geyerella americana*, and we agree with his conclusion. There are in the collections of *G. hessi* some specimens similar to the holotype of *G. americana*, but the total aspect of the collection shows the above-mentioned differences; however, we realize that truly accurate comparison cannot be made on the basis of one or two fragmentary specimens of *G. americana*. The brachial valves attributed to *Geyerella americana* are so unlike those of *G. hessi* that it seems unlikely the two species can be the same. The difference is emphasized by the wide separation of the two species in time.

*Geyerella hessi* more closely resembles some European species of *Geyerella* than *G. kingorum*, one of the other new species that occurs in the Glass Mountains. It differs from the type-species, *G. gemmellaroi* Schellwien (1900a:15, pl. 1: figs. 7a-b; Greco, 1942, pl. 151) in its fewer plications (*G.*

*gemmellaroi* has up to 40, averages near 30) that start farther from the pedicle beak and that do not branch more than once per plication (some on *G. gemmellaroi* branch up to three times in length of a plication), its more slender pedicle valve with interarea that is consistently concave in contrast to that of *G. gemmellaroi*, which on many specimens is strongly convex, and by the sharper angle between the edges of the interarea and the sides of the valve. The brachial valve of *G. hessi* is less convex, and the beak is blunter and less overhanging. Costellae on *G. hessi* normally parallel the plications or converge toward their crests, but in *G. gemmellaroi* they may parallel the plications in some individuals or on some parts of individuals, but in most they cross the plications and appear to be quite independent of them. *Geyerella rex* (DeGregorio, 1930:27, pl. 7: figs. 1–2; see also Greco 1942:156, pl. 21: figs. 1–8) differs from *G. hessi* in most of the above features, and, in addition, it is much more elongate and attains much greater size.

DISCUSSION.—This species was considered by King (1931:57) to be the same as *Geyerella americana* Girty. He remarked upon the strange occurrence of this species both in the Hess and Capitan formations, but he nevertheless equated the Capitan and Hess forms, stating that they agree “insofar as can be told from such an incomplete type specimen” (1931:57). Despite the fact that they do agree in many features, we consider it unlikely that the Hess and Capitan forms are one species, and we have chosen to consider their differences as more important than their similarities. In species as variable as those of *Geyerella* and *Meekella*, which attached directly to the substrate, it is almost impossible to evaluate specific identity of single specimens.

Girty (1909:202) identified as *Orthotetes distortus* var. *campanulatus* a small valve that was collected at the same locality as the holotype of *G. americana*. King (1931:57) considered this specimen to be a juvenile shell of *G. americana*. Girty had suggested that the shell might belong to a species of *Geyerella*, but he considered the plication to be an accidental feature. After studying many similar

juvenile shells of *G. kingorum*, new species, and a few of *G. hessi*, we have seen that the beginnings of plication are quite similar in those species to that in Girty's specimen, and, therefore, we agree with King that the plication is not accidental and that the specimen belongs with *G. americana*.

Our species is named for the late Mr. Leonard Hess, who helped our studies with his cordial permission to collect on his ranch.

### *Geyerella inexpectata*, new species

PLATE 125: FIGURES 5–36

Small for genus, variable, conical profile, brachial valve strongly convex; roundly elliptical in dorsal view; hinge narrow; sides rounded; anterior commissure with strong ventrad wave. Attachment surface usually small. Posterior unplicated for 5 to 10 mm, but marked by costellae of 2 sizes, larger ones marking off groups of 1 to 4 finer ones. Plications originating 5 to 10 mm anterior to beak, generally low, narrow, distant, variable in number and size, averaging about 12.

Pedicle valve a misshapen cone, moderately convex along ventral side and narrowly domed in anterior profile. Beak region usually slightly curved; interarea moderately long, flattened, with strong beak ridges; pseudodeltidium narrow, monticulus fairly strong. Median region longitudinally swollen to form ill-defined fold; flanks steep, and somewhat flaring.

Brachial valve fairly strongly convex, umbonal region narrowly convex, median region somewhat flattened, anterior flattened, deflected ventrally. Anterior profile moderately and broadly convex, sides flattened and sloping. Brachial valve inflated, anterior and lateral slopes steep. Anteromedial region somewhat depressed to form ill-defined fold and short broadly rounded tongue.

Pedicle valve interior with narrow spondylium and septum extending to about midvalve or slightly beyond. Brachial valve with moderately long cardinal process, narrowly forked distally with narrow but well-developed promontorium.

## MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 720d          |                            |                             |                  |                |                     |           |
| 150986a            | 17.7                       | ?                           | 22.3             | 13.4           | 13.0                | 15.0      |
| 150986b            | 16.7                       | ?                           | 20.3             | 13.0           | 10.5                | 14.0      |
| 150986c            | 15.7                       | ?                           | 20.5             | 11.4           | 10.8                | 13.7      |
| 150986d            | 18.9                       | ?                           | 22.8             | 13.5           | 10.3                | 14.7      |
| 150986e (holotype) | 22.6                       | ?                           | 28.0             | 14.2           | 12.3                | 13.2      |
| 150986f            | ?                          | 20.7                        | 28.4             | 17.9           | ?                   | 11.5      |
| 150986g            | ?                          | 22.4                        | 28.8             | 16.0           | ?                   | 9.8       |
| 150986h            | ?                          | 22.4                        | 26.9             | 14.0           | ?                   | 10.7      |
| 150986i            | ?                          | 21.6                        | 24.0             | 13.9           | ?                   | 8.8       |
| 150986j            | ?                          | 18.3                        | 20.2             | 10.0           | ?                   | 7.7       |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 707e, 719w, 720d, 726e.

TYPES.—Holotype: USNM 150986e; figured paratypes: 150986a–c, g, i, k–m; measured paratypes: 150986a–d, f–j; unfigured paratypes: 150986d–f, h, j.

DIAGNOSIS.—Small, irregularly costate *Geyerella* with narrow pedicle valve strongly domed in anterior profile.

COMPARISON.—This species, because of its small size and gently rounded contours, is completely unlike *Geyerella americana* Girty or *G. hessi*, new species. It is most like *G. kingorum*, new species, and attains the size of that species. It is, however, more plicate than the Wolfcampian species, with average about 10. The brachial valve of *G. inexpectata* is somewhat less umbonate and swollen than that of *G. kingorum*, and the anterior margin forms a distinct tongue unlike the margin of the Wolfcampian species. The pedicle valve interarea is more regular and appears to be less distorted than that of *G. kingorum*.

DISCUSSION.—*Geyerella inexpectata* is very rare, known only from the lenticular limestone bed that occurs at the base of the Word Formation (but is assigned to the Road Canyon Formation) on the east side of Gililand Canyon and in two other localities, where it is still rarer. The identification is attended with some difficulty because the species occurs with *Ombonia*, a genus similar to *Geyerella* in having a narrow spondylium and similar growth habits. *Ombonia* is seldom as distorted as *Geyerella*, its brachial valve and cardinal process are unlike those of *Geyerella*, and it is not costate.

*Geyerella kingorum*, new species

PLATE 119: FIGURES 1–31; PLATE 120: FIGURES 1–33; PLATE 124: FIGURES 1–10

*Orthothetina* cf. *Orthothetes mutabilis* R. E. King (not Girty), 1931:52, pl. 4: figs. 14, 15.

Small to moderately large, biconvex, shallow to deeply conical, normally somewhat irregular and distorted; outline transversely subelliptical to subtrigonal; hinge proportionately wide in juveniles (0.7–0.8 total width of shell), becoming narrower in larger shells 0.5–0.6 width of shell in moderate-size individuals to 0.35 in largest, ends of hinge distinct but nonauriculate, meeting sides of valves at nearly straight angle. Plications very weak to strong, coarse, rounded, irregular, many bifurcating, numbering 5 to 20, averaging 10, beginning 10 to 25 mm anterior to pedicle beak, hence juvenile and young adult shells unplicated. Costellae fine, fairly straight, often alternating in strength, added by insertion, converging over crests of plications near anterior margins of large shells; growth lines present but not prominent, normally one exceptionally strong at juncture of plicated and non-plicated parts of shell. Commissure coarsely plicate and minutely serrate also broadly undulating in some specimens.

Pedicle valve beak blunt to moderately sharp, normally distorted by attachment surface; valve rarely attenuate, more commonly broadly conical; interarea narrow, transversely flat, longitudinally concave to convex, frequently twisted, meeting sides of valve with only slight break in slope when meeting plane of commissure at angle of nearly 90°; pseudodeltidium narrow, between one-half and one-

third as wide as interarea at hinge, bisected by narrow monticulus.

Brachial valve moderately to strongly convex, with prominent overhanging beak; umbo swollen; posteromedian region inflated; lateral slopes short and steep; anteromedian region flattened.

Pedicle valve interior with strong teeth extending ventrally inside interarea as convergent dental ridges, about half way to beak widening into convergent dental plates that unite above anterior floor, forming a very short, narrow, Y-shaped spondylium, meeting median septum that extends for only a very short distance anteriorly along floor. Muscle marks consisting of faint striae and ridges within spondylium.

Brachial valve interior with broad, curved cardinal process, bifurcated for a short distance at free

end, each branch longitudinally slit along posterior edge, with minute serrations in each slit, branches joining about midway to form single crest of process along its proximal half. Chilidial boss narrow but thick, merging into convexity of upper convex part of shaft without a keel. Promontorium narrow but deep; gusset small; dentifers small, buttressed by promontorium; fulcral plates small; erismata diverging slightly into umbonal arch of valve, outlining a somewhat narrow posterior of muscle area, extending forward only a short distance along floor of valve. Muscle area in umbonal arch, slightly excavate, bisected by low, rounded myophragm; muscle marks obscure, consisting of longitudinal striae in muscle area and on inner surfaces of dentifer supports.

MEASUREMENTS (in mm).—

|                    | pedicle<br>valve<br>length | brachial<br>valve<br>length | maximum<br>width | hinge<br>width | interarea<br>length | thickness |
|--------------------|----------------------------|-----------------------------|------------------|----------------|---------------------|-----------|
| USNM 701k          |                            |                             |                  |                |                     |           |
| 150970a            | 3.0                        | 3.0                         | 3.9              | 3.0            | 1.5                 | 2.7       |
| 150970b            | 6.2                        | 5.2                         | 7.0              | 4.9            | 2.7                 | 4.8       |
| 150970c            | 7.0                        | 7.0                         | 8.3              | 5.4            | 6.4                 | 9.0       |
| 150970d            | 8.5                        | 8.5                         | 10.3             | 6.0            | 8.8                 | 10.9      |
| 150970e            | 13.2                       | 9.7                         | 12.3             | 7.0            | 10.0                | 15.6      |
| 150970f            | 14.0                       | 13.3                        | 15.0             | 7.3            | 6.0                 | 11.0      |
| 150970g            | 14.6                       | 13.5                        | 16.2             | 9.0            | 13.2                | 19.0      |
| 150970h            | 21.3                       | 16.6                        | 17.8             | 12.8           | 15.0                | 22.5      |
| 150970i            | 20.2                       | 21.0                        | 21.0             | 13.1           | 20.8                | 28.2      |
| 150970j            | 21.8                       | 17.8                        | 22.0             | 10.0           | 12.0                | 21.0      |
| 150970k            | 25.7                       | 25.7                        | 25.2             | 12.0           | 13.8                | 29.7      |
| 150970-l           | 23.4                       | 21.6                        | 27.7             | 12.5           | 15.9                | 28.0      |
| 150970m            | 26.1                       | 26.1                        | 26.6             | 12.9           | 20.0                | 29.6      |
| 150970n            | 27.6                       | 27.6                        | 27.3             | 14.9           | 23.0                | 36.1      |
| 150970o (holotype) | 37.5                       | 37.5                        | 43.7             | 22.0           | 28.2                | 38.8      |
| USNM 701h          |                            |                             |                  |                |                     |           |
| 150968b            | 38.2                       | ?                           | 42.8             | 23.0           | 23.2                | 26.1      |
| USNM 727c          |                            |                             |                  |                |                     |           |
| 153830a            | 36.5                       | 31.5                        | 36.6             | 18.7           | 24.0                | 37.5      |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2 to 14 of P. B. King), Lenox Hills Formation.

LOCALITIES.—Neal Ranch Formation: USNM 701, 701a, 701a<sup>2</sup>, 701c, 701d, 701h, 701k, 701-l, 722w, 726d, 727e; Lenox Hills: 705.

DIAGNOSIS.—Medium-size *Geyerella* with few plications that originate well forward of the beak.

TYPES.—Holotype: USNM 150970o; figured paratypes: 150968b, 150969, 150970c, e, 153509,

153510a-l, 153830a-d, 155104; measured paratypes: 150968a, b, 150970a-n, 153830a; unfigured paratypes: 152594a, c, d, f-i, k-m, 150964, 153830a, e, f.

COMPARISON.—*Geyerella kingorum* is characterized by its relatively few and irregular plications that start far forward of the beak and normally have rounded crests, by its shallow or bluntly conical pedicle valve that commonly is twisted or otherwise deformed, and by its comparatively small size. The only other species of *Geyerella* in the Glass

Mountains comparable to it is *G. inexpectata*, which has more plications starting farther back on the beak and is smaller on the average and more deeply conical.

Several species of *Geyerella* from Europe and Asia have been described, but only one resembles *G. kingorum*. That is *G. distorta* Schellwien (1900b:35, pl. 3: figs. 6-13), which differs in the deeper conical pedicle valve of the adult, more regular and more nodular plications, and greater maximum size. Other foreign species are larger and bear many more plications than either *G. kingorum* or *G. distorta*.

DISCUSSION.—The shape of *Geyerella kingorum* varies considerably, as in most species that grew attached directly to the substrate by the pedicle valve. Most individuals are twisted or distorted, many with broad scars of attachment near the apex or along one side of the pedicle valve. Many specimens have some of the plications stunted by contact with a foreign object on the substrate or with other individuals in clusters of shells. A few specimens have elongate pedicle valve beaks, but most are rather shallow cones, somewhat flaring toward the margins and some actually are cup-shaped. The characteristic twist of the pedicle valve that is so common in this species is normally rather regular as though the animal turned quite steadily as it grew. This twist is not present on all specimens, but, where seen, it characterizes the species; it is found commonly in one other species, *G. distorta* Schellwien from the Carnic Alps and Sicily. In addition to the twist, the pedicle valve also may be bent so that the interarea is concave or less commonly flat or convex.

Costellation may be weak to barely visible, largely depending on the preservation, and growth lines also vary in their strength. Internally, the juncture of the dental plates takes place high above the floor of the valve, or just above it; hence, the median septum may be rather high or very low. Normally the dental plates are fairly straight and symmetrical, but in some specimens they bend outward or are slightly crenulated, and in other specimens one plate is more strongly bent than the other. The cardinal process varies in its length, width, curvature, and depth of bifurcation, but none of this variation is extreme.

King (1931:52) identified several specimens from

the Gaptank and Neal Ranch formations as "*Orthothetina* cf. *Orthothetes mutabilis* Girty." These are fragmentary specimens that do not show all features clearly. His best specimen, that from R. E. King 91 (R. E. King, 1931, pl. 4: figs. 14a-b), is broken in such a way as to show two convergent dental plates, but matrix obscures the short median septum that lies below the juncture of the dental plates. Therefore, King considered the arrangement of plates to be like that of *Meekella*, rather than that of *Geyerella*. The shell is not plicated, but only obscurely sinuate with what appear to be the posterior ends of incipient plications beginning about 22 mm from the brachial beak. Many specimens of *G. kingorum* are unplicated at that distance or farther. King's specimens are identical in all important features to unequivocal specimens of *Geyerella kingorum* in the national collection, and undoubtedly they belong to that species.

The species is named for the King brothers, who outlined Glass Mountain geology.

### *Geyerella* species 1

A possible new species of *Geyerella* was taken at USNM 705m from the Lenox Hills Formation on Leonard Mountain. The specimens are incomplete and poor, but the strong plication of the exterior and the chunky form suggest a species comparable to *G. hessi*. The largest and best-preserved specimen is in the condition of the holotype of *G. americana*, with about half the shell preserved but with neither side perfect. The spondylium is clearly visible and the elongated cardinal process can be seen from the side. The plications are strong, distant, with 2 occupying a space of 10 mm. A brachial valve indicates a possible 24 costae on a large specimen.

MEASUREMENTS (in mm).—Length 59.6, width doubtful but estimated at 65, thickness about 58.

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation.

LOCALITY.—USNM 705m.

DESCRIBED SPECIMENS.—USNM 147736a-d.

DISCUSSION.—The four specimens of this species are all different and show the species to have been variable. Possibly this *Geyerella* could be identified as *G. hessi*, but, with the small size of the sample for comparison, it seems best to individualize it. At any rate, it helps to emphasize the intimate



relation between the fauna of the Lenox Hills Formation and that of the Decie Ranch Member of the Skinner Ranch Formation.

### *Geyerella* species 2

A single brachial valve of *Geyerella* was recovered from the residues from locality AMNH 21. The specimen is poorly preserved and considerably distorted from having lived in an unfavorable position. It is very strongly umbonate and the plication is marginal.

MEASUREMENTS (in mm).—Length 21, width 22, the hinge about 14.

TYPES.—Described specimen: USNM 150989.

### Suborder OLDHAMINIDINA Williams, 1953

#### Superfamily LYTTONIACEA Waagen, 1883

Ostreiform pseudopunctate brachiopods attached at posterior end. Pedicle valve varying from flat expansion to deep cone, having narrow, straight, simple hinge and series of lateral channels given off from median groove. Brachial valve pinnate and lobate, lobes fitting over lateral channels of pedicle valve. Cardinal process usually bilobed, but may be modified or aborted.

FAMILIES.—Poikilosakidae, Lyttoniidae.

DISCUSSION.—The Oldhaminidina constitute an aberrant branch of brachiopods that developed an ostreiform habit. They are rare in the Pennsylvanian Period, but they became one of the most characteristic forms of the Permian. The basic anatomy is outlined in the foregoing definition and is described in more detail under the families. Considerable speculation has centered about the brachial valve and the musculature that controlled it. Because the Oldhaminidina appear to divide naturally into two groups having parallel development, the questions of anatomy and biology are best discussed under the separate families.

The more primitive of the Oldhaminidina appear in the Late Pennsylvanian and continue as an obscure and rare group at least into the late Guadalupian. The more advanced types appear very late in the Pennsylvanian and continue in force into the Guadalupian in North America.

Grant (1972) suggested that the pinnate brachial valve of the Oldhaminidina is a modification of the

kind of ptycholophous lophophore that occurs in Productidina of the family Cooperinidae, Pajaud (1968). He speculated further (Grant, 1972) that the general form of the productidine lophophore was ptycholophous, and that the Oldhaminidina were derived from the Productidina some time during the Pennsylvanian.

TERMINOLOGY.—Some of the terms now applied to the oldhaminidines are not satisfactory and others are confusing. New terms are offered below to clarify some parts of the anatomy and to define better the stages of development.

ANATOMICAL TERMS.—The term *cowl* is suggested for the anterodorsad growing shell that produces the conical shape of the oldhaminidines. Williams (1953) visualized this as a separate plate having a suture line between the ventral and dorsal sides of the shell. This is not the case, because the growth of the conical forms is holoperipheral, a misshapen cone being produced when the anterior side grows faster than the posterior side, but a fairly symmetrical cone being produced when the two sides grow at nearly the same rate. Williams' term *posterior flap* is best restricted to the posteriorly growing wash or callus of attachment in oldhaminidines such as *Collemataria*, *Leptodus*, and *Oldhamina*. *Cowl* is used by us for the hoodlike, posterior side of the cone. When the cowl is prominent and the shell a fairly well-formed cone, the valve may be spoken of as *cowled*. Thus, the *flap* will be restricted to the posterior growing attachment, but *cowl* is used for the hoodlike structure growing in the opposite direction (anteriorly), thus producing a cone. The simpler and more familiar term *hood* is not used because of possible confusion with its use in the loop development of many terebratulid brachiopods.

Terms at once descriptive and easy to understand are needed to define the stages of lobe-to-septa development in the Oldhaminidina. The course of the evolution of these structures appears to be fairly well agreed upon, but the present terminology is inappropriate or confusing. The term *loop* is unfortunate because of possible confusion with the loop of the Terebratulacea. The use of generic names to define stages of evolution are seldom sufficiently definitive.

The visceral and mantle cavities of the primitive Oldhaminidina are surrounded by a wall herein

called the *vallum* (flange of Watson). In the primitive condition this wall probably was circular or nearly so, but in *Poikilosakos*, the most primitive Oldhaminidina having a complete vallum, it is thrown into lobes, one or more on each side of a deep median indentation. We suggest that the lobes that are closed toward the outer margin of the shell be termed the *outlobes* and that the ones closed toward the inside or middle of the shell be termed the *inlobes*. In the evolution of the two families of the Oldhaminidina, the outlobes are compressed in a direction parallel to the long axis of the shell. This tends to crowd the lobe walls together, and ultimately it makes a single ridge or septum of them. For the primitive condition of a wide lobe with walls distant the name *latilobate* is suggested. The outlobes of *Poikilosakos* and *Keyserlingina* illustrate this condition. The next stage shows the walls of the outlobes compressed toward each other with only a narrow space or groove between. This is called the *angustilobate* condition and is characteristic of *Eolyttonia* and early formed parts of other genera. When the walls of the outlobes have been compressed together to form a single ridge, the condition is termed *solidiseptate*. These solid ridges are the *septa* of most authors and are best seen in parts of *Leptodus*, *Collemataria*, and other advanced genera. The ultimate stage of development of the lobes is that seen in *Oldhamina*, in which they are thin, with a knife edge, and strongly oblique. This type is termed *anguliseptate*, which, as explained elsewhere, may develop under conditions that produce a concave shell. They are also seen in *Loxophragmus*, but generally they are rare in occurrence. In one genus the compressed lobes are broken into beads and dashes, a condition that is herein called *moniliseptate*.

All of the names suggested above for the outlobes can be applied to the median inlobe. This is compressed laterally from a *latilobate* condition, as in *Keyserlingina*, to an *angustilobate* form, as in *Eolyttonia*, to a *solidiseptate* character or median ridge, as in *Leptodus*, *Collemataria*, and others. An angular stage like that of the lateral lobes of *Oldhamina* does not occur. A *moniliseptate* type of median ridge is seen in several genera, such as *Collemataria* and *Leptodus*, and it is the condition on which the Termiers based the genus *Gubleria*.

It is also well formed in *Coscinophora*. The above terms define the evolution of the lobes to septa, but a nomenclature is needed to define the stages of evolution of the genera.

The stage of the vallum displayed by *Keyserlingina*, formerly known as the *Keyserlingina*-stage, is herein termed the *circumvallate* stage in allusion to the continuous nature of the vallum. When the vallum is breached, as in *Eolyttonia*, and compression of the outlobes and median inlobe occurs, the condition may be called the *pervivallate* stage in allusion to the break in the vallum at the anterior. This is the *Eolyttonia* stage of several authors. After this stage the vallum is permanently broken and the lobes are compressed to form solid septa. This state is called the *septivallate* stage, and the final stage in which the septa become uniform and sharp-edged is herein called the *terminivallate* stage or the *Oldhamina* stage of authors. *Coscinophora* represents a stage in which the outlobes and median inlobe are broken into beads and dashes. This is termed the *fragmentivallate* stage. The foregoing terms are designed to describe the condition and fate of the vallum during the phylogeny of the Oldhaminidina.

GENERIC CHARACTERS OF THE OLDHAMINIDINA.—Generic characters of the Oldhaminidina appear on the exterior as well as the interior. The external form of the pedicle valve, within limits, is a helpful guide to genera. In the Poikilosakidae the earliest member is attached by its entire surface, but later members form cuplike structures. The degree of complication of the cup is useful in defining genera.

In the Lyttoniidae the form of the pedicle valve is also useful in defining genera. None of these except *Paralyttonia* is attached by its entire surface, and all form a conical cup of varying degree of development. *Eolyttonia* forms misshapen cones, but *Pirgulia*, with its flattened cornicopia shape, is very distinctive. This cone is so slender and sharply pointed that speculation regarding its form of life is certain to arise (Rudwick and Cowen, 1968). It was undoubtedly attached in the young stage, but it must have lived loose in the adult stage. The majority of the Oldhaminidina are flattened or only gently convex on the ventral side, but *Oldhamina* is strongly convex on this side, a condition helping to distinguish this genus.

The type of attachment of the pedicle valve is also helpful, with other characters, in the definition of a genus. Many genera such as *Eolyttonia*, *Coscinophora*, and *Loxophragmus* are attached by a small area at the apex of the cone, but *Collemataria*, *Petasmaia*, and *Leptodus* have a broad flap at the posterior that cements them to the substrate. This is commonly so strong that the specimen, when broken from its mooring, often carries part or all of the host with it, when it dies, and is transported by currents from the site of growth. These two types of holdfasts involve shells of completely different form. *Oldhamina*, in its young stages, seems to have been affixed like *Collemataria*, but, on breaking away from its moorings to live free, the mantle continued to deposit shell over the posterior to produce a sort of rump.

The shape of the shell and the kind of mooring used by it are thus important characters in definition, but they do not define a genus until they are combined with various features of the interior. Interior characters useful in generic definition are: the hinge, the vallum and its development, and the muscles. No characters found on the inside of the brachial valve have proved of value in the generic identification.

The hinge generally is fairly uniform throughout the Lyttoniidae except for the new genus *Choanodus*. The hinge of the latter is specialized and more elaborately developed than any other of these groups of brachiopods. The hinge, thus, has limited value, but it must be studied and described.

The vallum and its aberrations are extremely valuable in generic characterization, but they must be used with caution because of their repetitious nature within genera and in the same specimen. In general the Poikilosakidae are characterized by a complete vallum or by one that is incomplete only at the anterior. *Poikilosakos*, therefore, is in the circumvalate stage and all of the outlobes and the median inlobes are latilobate. Later members of this family become pervallate, the lobes remaining latilobate, but some specimens show compression and a tendency toward the angustilobate condition. Late members of the Poikilosakidae also show a tendency for the outlobes to alter from strictly lateral to an anterolateral direction. The Poikilosakidae, consequently, retain the primitive character

of its vellar lobes, only slightly modified throughout their phylogeny.

The Poikilosakidae are characterized by the deep median lobe of the vallum, which is reflected in a deep median slit in the pedicle valve. This feature is characteristic of all Poikilosakidae and early Lyttoniidae. In more advanced Lyttoniidae elimination and closure of the median slit is characteristic of the stratigraphically younger genera.

The vallum is the basic pattern for the Lyttoniidae as well as the Poikilosakidae. The young of all of the genera in the Glass Mountains have a well-formed vallum that is in either the circumvallate or pervallate stages. Furthermore, the earliest or first formed lobes remain latiseptate or become angustiseptate and retain these characters throughout their life, although lobes added later are in more advanced stages. Few of the genera are provided with lobes or septa that are uniform throughout the shell from posterior to anterior except in young stages. Early forms of *Eolyttonia* have most of the lobes in the latilobate or angustiseptate stages throughout the shell, but later species have more advanced solidiseptate lobes. *Oldhamina* and *Coscinophora* have fairly uniform development of lobes throughout, but some individuals of these two have aberrant lobes. The beaded ridges of *Coscinophora* in some specimens pass into a solidiseptate type of lobe (a remnant?), whereas the rest of the shell, including the median lobe, is moniliseptate. The lobes and their end development as septa are thus difficult to use in the characterization of genera. Usually the observer must rely on the predominant development within specimens and within collections of the same species.

One of the much discussed questions about the Oldhaminidina is whether or not the brachial valve could be moved. The presence of muscle marks in the pedicle valve of several of the genera and the presence of a cardinal process make it clear that the valves could be opened and closed. Other considerations also lead to this conclusion. We have used the nature of the muscle marks as a means to separate the Poikilosakidae from Lyttoniidae. The former family is characterized by a single asymmetric muscle scar on the right side of the pedicle valve just anterolateral to the hinge in the interior of the shell. This scar is conspicuous and is often made more so by being encased in a sheath. In

addition, an asymmetrical cardinal process appears in the brachial valve. *Keyserlingina* has a conical form, is in the circumvallate stage, and thus resembles *Pseudoleptodus*, but it differs in the lack of a muscle scar. Thus, the presence of a single asymmetrical muscle scar is used to distinguish the Poikilosakidae from the Lyttoniidae. This seems to be a more substantial character than a general lack of symmetry in these attached shells, as previously used (A. Williams, 1953b).

Three genera of the Lyttoniidae, *Petasmaia*, *Leptodus*, and *Coscinophora*, are provided with distinct muscle marks, and the sides of the muscle area are generally bounded by ridges or septa. Most other genera fail to show distinct traces of muscles. These muscle patterns differ from those of the Poikilosakidae in having bilateral symmetry. In each genus the presence of the muscle scars was used by us as one of the generic characters. *Collemataria*, new genus, for example, has the general form of *Leptodus* and is solidiseptate, but septa are slightly more advanced in the Asian genus. The chief difference between the two, however, seems to be the presence of the muscle scars in *Leptodus* and their complete absence in the American genus.

In summary, it may be stated that the important generic characters are the external form of the pedicle valve combined with various arrangements of the stages of lobe and septal development. The brachial valve does not share significantly in generic characterization. The Oldhaminidina are greatly different from other brachiopods in their generic characters, although these too are generally best defined on external features combined with internal family characters.

#### CLASSIFICATION OF THE OLDHAMINIDINA.—

Superfamily LYTTONIACEA Waagen, 1883

Family POIKILOSAKIDAE Williams, 1953

*Poikilosakos* Watson, 1917

*Pseudoleptodus* Stehli, 1956

*Choanodus*, new genus

*Sceletonia*, new genus

Family LYTTONIIDAE Waagen, 1883

*Oldhamina* Waagen, 1883

*Coscinophora* Cooper and Stehli, 1955

*Eolyttonia* Fredericks, 1923

*Gubleria* Termier and Termier, 1960

*Keyserlingina* Tschernyschew, 1902

*Leptodus* Keyser, 1882

*Oldhaminella* Wanner and Sieverts, 1935

*Pirgulia* Cooper and Muir-Wood, 1951

*Paralyttonia* Wanner and Sieverts, 1935

*Rigbyella* Stehli, 1956

*Collemataria*, new genus

*Petasmaia* Cooper and Grant, 1969

*Loxophragmus*, new genus

Family BACTRYNIIDAE Williams, 1965

*Bactrynum* Emmrich, 1855

Family SPINOLYTTONIIDAE Williams, 1965

*Spinolyttonia* Sarycheva, 1964

REMARKS ON THE CLASSIFICATION OF THE OLDHAMINIDINA.—The Family Bactryniidae contains a single genus that is quite aberrant for an Oldhaminidina, and it might be questioned just where the genus belongs. The cardinal process of *Bactrynum* is a single ridge quite unlike the bilobed structure characteristic of the Lyttoniidae or even like the off-median single ridge of the Poikilosakidae. Furthermore, the brachial valve of *Bactrynum* is unlike that of the Oldhaminidina in being a solid plate, and not pinnate, as in the Permian genera. A probable separate origin in the Triassic should be sought.

The subfamily Spinolyttoniidae and its single genus is looked on by us with extreme skepticism. This family was created by Williams for the genus *Spinolyttonia* Sarycheva (1964:69) for a lyttoniid "Resembling *Leptodus* but with septal apparatus like that of *Oldhamina* and with spines on external postlateral areas of the pedicle valve." In our experience we have not seen spines on any member of the Oldhaminidina. The USNM collection includes thousands of specimens, many in exquisite preservation, but not one has been seen with spines of attachment. We suggest that the Russian specimen has been misinterpreted and that the spines attributed to the lyttoniid actually belong to some cementing productid whose body has been stripped off but whose spines have been left adhering to the lyttoniid. This is not an infrequent occurrence in the Glass Mountains specimens. We have figured (Plate 133: figures 5, 6) a specimen so attached to *Institella* that it appears to have spines when viewed from the dorsal side.

The origin of the Oldhaminidina is still not known. Fredericks suggested that they were derived from a marginiferoid, the margin of the productid forming the primitive vallum of the Oldhaminidina. Invagination of the margin supposedly set off the evolution of the group. The marginiferids



were cementing forms only in immature stages and the spines would have had to be eliminated.

### Family POIKILOSAKIDAE Williams, 1953

Lyttoniaceae consisting of flat expansions or irregular cones with interior varying from circumvallate to early pervivallate stages. Pedicle valve having single asymmetrical diductor scar and brachial valve with modified cardinal process. Lateral lobes usually few in number. Brachial valve deeply slit medially.

GENERA.—*Poikilosakos* Watson; *Pseudoleptodus* Stehli; *Choanodus*, new genus; *Sceletonia*, new genus.

This family includes the simplest and most primitive of the Oldhaminidina. It was thought that *Cardinocrania* Waagen was the most primitive member of this family, but it is probably the young of *Leptodus* or some kind of richthofeniacean rather than a separate genus. At any rate, the genus appears rather late in the geological column for the originating or most primitive form of the family, *Poikilosakos*, which is the oldest known genus and the most primitive of all. It maintains its primitive form well into the Permian, although it is not always easy to decide whether one is dealing with a primitive *Poikilosakos* or the young of *Pseudoleptodus*.

Perhaps the most primitive species of *Poikilosakos* and the oldest so far as known is *P. petaloides* Watson, the first described species. This exhibits its primitive nature by attaching its entire ventral surface, the margin nowhere turning dorsally except by accidents of growth. This species also exhibits well the most distinctive character of the family, i.e., the single eccentric diductor scar that is commonly partly encased in an elongated sheath. This feature and the circumvallate interior characterize the group as it is now constituted throughout its life. Generic differentiation takes place, not in modification of the interior, but rather in the development of the conical form. This reaches its maximum in *Pseudoleptodus* in the Capitan Formation of the Guadalupian and its equivalents, the members of the Bell Canyon Formation. It also reaches a large size in lenses between the Willis Ranch and Appel Ranch members of the Word Formation.

*Pseudoleptodus* is not the only genus in the

family to develop the erect conical form. This was also adopted by the new genus *Choanodus*, but, in addition, this genus developed the most complicated articulatory apparatus seen throughout the suborder. The corrugated surfaces established on the posterior face of a cone of shell substance on each side of the hinge to articulate with corrugated flanges on the hinge of the brachial valve are unique. In addition to the unusual hinge, *Choanodus* also developed a strong conical form. Its musculature, however, is obscure; nevertheless, its type-species has an eccentric anterior thickening on the right side of the posterior region that can be interpreted only as the site of a large muscle. The second species assigned to *Choanodus*—*C. perfectus*, new species—fails to show any positive trace of the muscles and is placed in this genus because of the complicated articulatory apparatus that it possesses in common with the genotype.

In his definition of the family Poikilosakidae, Williams (1953b:287) stressed the irregular development of the internal lobes of the pedicle valve and the consequent irregular lobation of the brachial valve. We believe that much of the irregular development, as in all brachiopods, is induced by the accidents of attachment and is not a family characteristic. Many of the Lyttoniidae also show irregular development of the lobes, some of which can be traced to an uneven site of attachment, but others cannot be so readily explained. For example, it is common for an otherwise symmetrically formed oldhaminidine to develop one or more bifurcated lobes on one or both sides. It seems reasonable to believe that, given ideal conditions, *Poikilosakos* and the genera evolved from it would develop symmetrical forms, as any other brachiopod would. *Poikilosakos* is an extremely rare genus, and its developmental trends, in view of the few specimens known, can hardly be said to be well known. We have, therefore, not emphasized the unequal character of the lobe development, but we have featured the eccentric or asymmetrical nature of the musculature, which is not an evanescent feature dependent upon attachment. This eccentricity undoubtedly arose because of the adoption of attachment, but, once established, it is a uniform feature of the family.

Williams (1953b:285) placed *Cardinocrania* Waagen, *Paralyttonia* Wanner and Sieverts, and *Adri-*



*ana* de Gregorio in this family. As noted elsewhere, we believe *Cardinocrania* to be the young of *Leptodus*. The specimen figured by Wanner and Sieverts (1935, pl. 6: figs. 1, 2), in our opinion, is probably the young of a *Poikilosakos*, probably *P. variabile*. Both of the authors' specimens of "*Cardinocrania*" exhibit the eccentric muscle on the right side, as in *Poikilosakos*. The specimens probably have nothing to do with *Cardinocrania* (= *Leptodus*) from the Salt Range of Pakistan.

*Paralyttonia*, in our opinion, was correctly excluded from the Poikilosakidae by Williams, et al., (1965:519) because it has symmetrical musculature. It does, however, have some features of the Poikilosakidae, such as the lobed posterior margin of the brachial valve, a feature that it shares with *Rigbyella* Stehli, another genus that suggests the Poikilosakidae superficially but lacks the requisite family characters.

*Adriana* is the last of the genera that we exclude from the Poikilosakidae and from the Brachiopoda as well. The figure made by de Gregorio (1930, pl. 9: figs. 1-5) is very unsatisfactory, and it is not clear that the object interpreted as the brachial valve (Williams, et al., 1965:H520, figs. 3a, b) actually is, in fact, a brachial valve. Assuming that it is, other details of the interior are lacking that make it impossible to assign the genus intelligently (see also Rudwick and Cowen, 1968:43). Licharew (1964) suggested that these forms are algal, an opinion that seems very likely to be true. We have examined Sosio material very similar to that illustrated by de Gregorio and feel confident that, whatever the origin of these structures, algal or otherwise, they are not brachiopods.

### Genus *Poikilosakos* Watson, 1917

PLATE 127: FIGURES 19-32

*Poikilosakos* Watson, 1917:212-219.—Dunbar and Condra, 1932:272.—Wanner and Sieverts (part), 1935:212.

*Poikilosakos* is a rare genus that forms flat expansions on other shells, and has a loosely articulated fragile brachial valve that is not easily found. It may also be overlooked because of its confusing shape, masking it in the debris of acid residues. The original discovery of the genus was unusual because 20 specimens were found together, attached to the smooth surface of a nautiloid cephalopod

shell. In the Glass Mountains and Sierra Diablo the genus has proved unusually rare. It is by the greatest good fortune that these attached shells were found or that their brachial valves had been preserved. The genus is not well known, therefore, and has not been discovered widely in upper Paleozoic rocks.

In the United States, *Poikilosakos* has been found on several hosts. In the Wayland and Gonzales shales of the Graham Formation in north-central Texas, they appear rarely on the broad, smooth, large nautiloids common to this part of the column. They also have been found on crinoid stems in the Wayland Shale. A few have been taken attached to other brachiopods, but they seem to be rare on such hosts. In the lower Bone Spring Formation one specimen was found attached to a spreading bryozoan colony.

Trends noted in the discussion of the family relate to the external form and the development of the lobes. Inasmuch as these affect the form of the brachial valve, they need not be discussed separately here. The earliest genus is *Poikilosakos*, which has the simplest form. It must have resembled *Cardinocrania*, now considered as the probable young of *Leptodus*, and also it may have resembled, to some extent, *Pseudoleptodus primitivus*, new species, but probably it lacked the strong median invagination. Perhaps the best-developed *Poikilosakos* is *P. petaloides* Watson, but the brachial valve interior of this species is still unknown. We are reserving the name "*Poikilosakos*" for the flat expansions and using Stehli's name "*Pseudoleptodus*" for subconical and conical poikilosakids.

Throughout the life history of the family the interior of the pedicle valve has a complete vallum that is latilobate, although there is some constriction of the lobes in the latest species of the Capitan Formation. In the early forms the lobes culminate medially in a strong narrow emargination that extends nearly to the posterior. In later genera and species this median lobe of the vallum becomes isolated from the lateral lobes. Early isolation of the median lobe is a feature of the family Lyttoniidae.

The Poikilosakidae in North America appear in the lower part of the Cisco Series of Texas and in the corresponding part of the Virgil Series of Kansas. It ranges from this part of the Pennsyl-

vanian into the Capitan equivalent (Hegler Member of Bell Canyon Formation). In Russia one species, *P. tschernyschewi* Fredericks, is described from the Sakmarian Stage. Other described species are doubtful. *Poikilosakos dzhulfensis* Sarycheva (1964) does not have the eccentric diductor nor do the specimens from Iran referred to by Glaus (1964). Both of these probably involve the young of *Leptodus*.

The entire surface of the pedicle valve of *Poikilosakos* is adherent to the substrate. It is only to this type of shell that we apply the name "*Poikilosakos*"; the conical forms are referred to *Pseudoleptodus* Stehli. The pedicle valve is reminiscent of an egg about to be fried. The amorphous attachment of the shell, thin and spreading, but the circumvallate visceral area corresponding to a broken yoke. The spreading attachment is pseudopunctate and also suggests the callus flap at the rear of the larger oldhaminidines such as *Leptodus*. The intervallate material is like that of the extravallate shell, finely pseudopunctate and very thin.

*Poikilosakos* is so simple that few characters are available for classification. One of these is the hinge, that, although primitive, is prophetic of all the Oldhaminidina. It also suggests that of the richthofeniids. The hinge is essentially the reverse of that of normal brachipods in that the hinge processes or "teeth" are in the brachial valve, rather than the pedicle valve, and the sockets are in the pedicle valve. The hinge is straight, forming a narrow transverse groove with elevated margin posterior to it. The elevated posterior margin may be marked by one or more fine ridges parallel to the hinge. At the middle a slight bulge of the posterior margin overhangs the morphological center of the valve. Anterior to each side of the hinge are triangular areas, usually slightly sunken, from which the vallum extends and which are usually papillose or minutely striated longitudinally. No definite sockets appear in this apparatus, the posterior margin of the brachial valve fitting snugly into the transverse groove, with the median bulge, when present, helping to keep the valve in place. This median bulge is prophetic of the prominent one seen in the new genus *Choanodus*.

One of the most important features of the pedicle valve of *Poikilosakos* is the musculature, which is significant for its lack of symmetry. A single elon-

gated scar appears on the right side when the shell is seen from the inside. In some specimens this scar is so long that it extends nearly to midvalve. Usually it is sheathed wholly or partly by shell material on its sides. Speculation has centered on the function of this muscle, whether it opened or closed the valve or whether it served either function. The fact that it is in the position of a diductor and the fact that the groove of the hinge shows signs of wear indicate to us that this muscle was a functioning diductor.

The most remarkable feature of the pedicle valve of *Poikilosakos* is the lobate wall, herein called the *vallum*, that defines the visceral and mantle cavities of the animal. This originates at each end of the hinge, extending anterolaterally and usually sinusously or moderately lobed along its posteriormost course. Laterally it defines one or more lobes and terminates in a median lobe that extends posteriorly for half or more of the length of the valve. This part of the vallum commonly is produced into a narrow curve or perhaps a sharp inverted V. Usually the median lobe is the most elevated of all, and, in some specimens, it may be excavated at its termination so as to form a short tube. The vallum is commonly bevelled or grooved on the inner face to receive the outer edge of the brachial valve. Usually the inlobes, toward the animal's midline, are stronger and more elevated than the outlobes extending outward toward the animal's periphery.

Except for scraps, the brachial valve of *Poikilosakos* hitherto has been unknown, and by 1973 the interior of the type-species is yet to be found. As postulated by Watson (1917) and described by Dunbar and Condra (1932) from fragments, the brachial valve fits on the inner slopes of the vallum and conforms to the outlines of this wall. A specimen from the Plattsmouth Limestone of Kansas in the United States National Museum (USNM 137498) exhibits the exterior to perfection. The hinge is very narrow, measuring 2 mm as compared to the maximum width of 15 mm. On each side of the hinge are two small ears or points that help in articulation. The growth of the shell can be traced in strong concentric lines, showing it to have originated as a bilobed transverse individual. The posterior margin is undulating. The median cleft that surrounded and is in contact with the median

inlobe of the vallum is wide and partly closed at its apex by a short web.

The interior of the brachial valve is simple. In the hinge region the narrowed posterior is bounded on each side by a triangular area—in some, faintly striated longitudinally and marked on the anterior side that faces the interior by a low ridge. The cardinal process is short, flattened, and gives the appearance of having been pushed laterally so that it is oblique to the valve floor with a narrow space between it and the floor. The myophore is seldom clear, but it appears to be bilobed. Although the cardinal process appears to be median in position, it is asymmetrical like the single muscle scar that opposes it. The lobe of the right side of the cardinal process is usually the larger.

The visceral region of this valve lies between the hinge and the median cleft. This part usually is moderately deep and is divided anteriorly by a low median ridge that rises to the proportions of a median septum in some instances. No adductor scars have yet been observed on either side of this ridge, but the animal must have had adductors to close the valves.

The lateral margins of the lobes generally are inflected in a ventral direction and are somewhat thickened where they make contact with the vallum. No definite structures appear inside the concave lobes, but, in one shell, low ridges parallel to the inflected lobe edge are visible; it is not clear what they mean.

**TYPES.**—Figured specimens: USNM 137498, 148041, 148045a, b, 148046, 148048a, 148049, 148050a–c, 150708.

### *Poikilosakos informis*, new species

PLATE 132: FIGURES 22–37

*Poikilosakos petaloides* Stehli (not Watson), 1954:306.

Large, variable without definable shape and attached by entire surface to substrate. Interior with slightly elevated vallum forming 2 or 3 lateral and 1 anterior lobe. Median lobe moderately wide, reaching posterior to midvalve, usually angular and slightly excavated at angle in old specimens. Adductor scar short, with marginal thickenings.

Brachial valve with narrow and short body, usually shallow; lobes 2 to 3 lateral and 1 short anterior; margins slightly reflected dorsally. Surface

smooth. Interior with low median ridge and minute, eccentric cardinal process.

**MEASUREMENTS** (in mm).—Paratype (USNM 150691): length 12.9, maximum width 18.4?, hinge width 2.3, height nearly flat; holotype (USNM 152619a): length 22.0, maximum width 22.8?, hinge width ?, height none; brachial valve of paratype (USNM 150694a): length 17.2, maximum width 16.1, hinge width 3.3, height ?; paratype (USNM 150694b): length 14.0, maximum width 18.7, hinge width 3.3, height ?

**STRATIGRAPHIC OCCURRENCE.**—Bone Spring Formation (base), Skinner Ranch Formation (base).

**LOCALITIES.**—Bone Spring: AMNH 625, 628, 629, 631, USNM 728f; Skinner Ranch: USNM 705a.

**DIAGNOSIS.**—Large *Poikilosakos* with 3 lateral lobes and 1 anterior lobe, large and formless, attached by the entire surface.

**TYPES.**—Holotype: USNM 152619a; figured paratypes: 152619b, c, 152620a, b, 150693, 150694a, b, e; measured paratypes: 150694a, b; unfigured paratypes: 150694c, d.

**COMPARISON.**—It is difficult to compare satisfactorily specimens as amorphous as *Poikilosakos*, but, if enough specimens can be obtained, a general, vague sort of shape can be defined. The vallum also has characteristics of its own that may contribute to species differentiation. Few pedicle valves of *P. informis* are known, but several specimens of the brachial valve have been collected. Compared with *P. petaloides*, the vallum is stronger and thicker in the Pennsylvanian species and the invaginations of the vallum are much narrower than in *P. informis*. Furthermore, *P. petaloides* has four lateral lobes in the adult, but *P. informis* appears to have only three. According to the form of the vallum of *P. petaloides*, its brachial valve would be more elongate than that of *P. informis*, which is transverse.

The only described species outside North America is *P. tschernyschewi* Fredericks (1927) from Krasnoufimsk. It differs from both American species in its transverse form and much larger size.

**DISCUSSION.**—As might be expected, *P. informis* is better represented by brachial valves than by pedicle valves. The attached forms can only be found on the larger lumps of bryozoa or other massive skeletal forms, and these usually are rare in the

residues. Recognition of the brachial valves because of their odd form is often difficult.

### *Poikilosakos* species 1

Small, subcircular, about 8 mm in diameter, attached by entire surface. Lobes irregular, wide, and with thick margins. Muscle scar unusually long, measuring about 4 mm, not tubular. Specimen attached to *Reticulatia* from USNM 718e.

Types.—Described specimen: USNM 150708.

### *Poikilosakos* species 2

PLATE 155: FIGURE 7

Small, transversely oval in outline, anterior margin slightly elevated. Vallum posteriorly and laterally elevated but nearly obsolete at anterior. Hinge very narrow; muscle scar long, enclosed on sides by moderately strong elevation. Median channel wide but with vallum scarcely visible. Length 11.6 mm, width 17.6 mm, hinge width about 1.5 mm. Specimen from USNM 706e.

Types.—Figured specimen: USNM 153581a.

DISCUSSION.—The lifting of the anterior margin is a tendency toward *Pseudoleptodus*. The specimen is attached on the inside margin of a large *Derbyia pannucia*.

### Genus *Pseudoleptodus* Stehli, 1956

*Pseudoleptodus* Stehli, 1956a:311.

Cowled Poikilosakidae having fairly symmetrical form, vallum of pedicle valve anteriorly incomplete in late species. Circumvallate to pervallate.

TYPE-SPECIES.—*Pseudoleptodus getawayensis* Stehli (1956:312, pl. 41: figs. 2, 5; pl. 42: figs. 1, 3).

COMPARISON.—As mentioned by Stehli (1956), this genus has the form and other characters of *Keyserlingina* of Tschernyschew (1902), which never was described or figured. All illustrated specimens of *Keyserlingina* are matrix filled or in matrix, making the interior characters difficult to describe and illustrate. Possibly because of these difficulties, the several authors who described species of this genus failed to record the presence of the median muscle scar and sheath characteristic of the family Poikilosakidae. This character is sufficiently conspicuous to be recorded on interior im-

pressions, as it is in *Poikilosakos tschernyschewi* Fredericks (1927). It seems clear, therefore, that *Keyserlingina* is in a separate line of development from that of the Poikilosakidae. The same holds for *Chaoella* Licharew, which now is regarded as a synonym of *Keyserlingina*. In the description of this genus, Licharew (1931) made no mention of asymmetrical musculature.

The conical form, which is strongly developed in some *Pseudoleptodus*, is sufficient distinction from *Poikilosakos*, a genus that is reserved for completely attached species.

DISCUSSION.—As herein interpreted, *Pseudoleptodus* is a more prolific genus than *Poikilosakos*. It probably was fairly abundant locally, but its attached habit prevented wide distribution. Obviously the attachment was not strong enough to prevent many individuals from being ripped from their moorings, or we would not have in hand as many specimens as we have collected. Most shells were attached by an apex of a size varying even within the species.

The pedicle valve presents few features different from *Poikilosakos* except the more advanced character of the vallum in late species. Some species of *Pseudoleptodus*, such as the type-species, have the outlobes nearly at right angles to the median lobe. Others, such as *P. guadalupensis* Stehli, have the outlobes extending anteriorly at a strong angle to the median lobe. This condition may be a reflection of the long, slender form of that species, but there is a tendency in fairly circular forms such as *P. conicus*, new species, for the outlobes to become moderately to fairly strongly oblique in large and fully grown specimens.

In all species of *Pseudoleptodus*, the outlobes usually are widely separated, but the inlobes in many species are narrowly compressed (anguistilobate) and thus resemble the so-called septa of early members of the Oldhaminidae in an early pervallate stage. Anteriorly, in some late species, the vallum becomes incomplete, the walls of the median lobe dying out distally as do the walls of the anteriormost of the outlobes. This is a trend toward the condition seen in most of the Oldhaminidina.

The brachial valve of *Pseudoleptodus* is similar to that of *Poikilosakos* internally as well as externally. It is common for one side of the brachial



valve to be developed differently from the opposite side, a feature that seems to take place for no apparent reason in shells that are otherwise symmetrically formed. It is also common for the posterior margin of the posteriormost lobe to be undulatory. *Pseudoleptodus* may develop more lateral lobes than usual in *Poikilosakos*, chiefly because the conical form permits anterior growth only to the specific limits of the animal. All specimens of all species showing the cardinal process indicate that this character is like that of *Poikilosakos* and thus in accordance with the eccentric character of the pedicle valve musculature.

Species of *Pseudoleptodus* occur in all parts of the Glass Mountains sequence and also in most of the section in the Guadalupe Mountains and the Sierra Diablo. Although specimens are rare and usually hard to find in the residues, ultimately a fair lot of them was obtained and some of their secrets revealed.

*Pseudoleptodus* appears also to be represented outside of North America. Examination of Wanner and Sieverts' (1935:212, pl. 6: figs. 8b, c) figures of *Poikilosakos variabile* indicate to us a relationship to Stehli's genus. This conclusion is based on the curved edges of the specimen, indicating a conical form, and on the presence of the sheathed muscle scar. The other specimens identified as this species by Wanner and Sieverts do not have the eccentric muscle scar, and, in some of them, symmetrical muscle scars are clearly indicated, suggesting relations to *Leptodus*, rather than to the Poikilosakidae. We believe that the specimens figured by Wanner and Sieverts (1935, pl. 6: fig. 1, 2) as *Cardinocrania* and that possesses the characteristic, asymmetrical scar of the Poikilosakidae should be referred to *Pseudoleptodus*. Most likely they represent the young "*Poikilosakos*" *variabile*, illustrated on the same plate.

### *Pseudoleptodus annosus*, new species

PLATE 127: FIGURES 2-18

Small, subcircular in outline, conical to subconical in form, depending on degree of attachment, those with small attachment surface becoming more strongly conical. Hinge narrow; lateral and one short anterior lobe; median region marked by junction of vallum from each side, strongest and

highest at midvalve, forming narrowly rounded lobe. Interlobal spaces outside vallum smooth; adductor scar long and very narrow, located in nearly completely tubular sheath.

Brachial valve bluntly lobate, lobes broad and shallow; exterior surface smooth. Interior with minute excentric cardinal process.

MEASUREMENTS (in mm).—Holotype (USNM 150697d): length 11.2, maximum width 12.2, hinge width 3.3, height 6.2; paratype (USNM 150697a): length 10.6, maximum width 13.5, hinge width 3.7, height 3.0; paratype brachial valve (USNM 150697c): length 8.2, maximum width 10.7, hinge width 2.0, height?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch Member), Cherry Canyon Formation (lower Getaway Member).

LOCALITIES.—Willis Ranch: USNM 706; Getaway: 732.

DIAGNOSIS.—Small, conical to subconical *Pseudoleptodus* with thick, median lobe.

TYPES.—Holotype: USNM 150697d; figured paratypes: 150697a-c, 150698a.

COMPARISON.—This species is characterized by its small size and thus is distinguished readily from all of the larger species such as *P. guadalupensis* (Stehli), *P. granulatus*, new species, and *P. getawayensis*. It is larger than *P. primitivus*, new species, and has more lateral lobes. Furthermore, the median lobe of *P. annosus* is not as strongly tubular as that of *P. primitivus*, which is extremely developed in this respect.

DISCUSSION.—Too few specimens of *P. annosus* are known to be sure whether this is an adult or a partially grown form. The fact that specimens of similar size have been found in the Glass Mountains and the Guadalupe Mountains suggests that the specimens represent fully matured individuals. One specimen (USNM 150697d) that shows its attachment scar has a large cowl. This specimen was attached to a cylindrical object and apparently was forced to develop the cowl to protect itself on its host. Specimens on flat objects did not develop a long cowl.

### *Pseudoleptodus conicus*, new species

PLATE 128: FIGURES 6-36; PLATE 129: FIGURES 1-19

Pedicle valve subcircular in outline but variable, depending on substratum; attaining diameter of



about 20 mm in largest specimen, forming misshapen cone. Surface of attachment varying from small point to large part of surface; lateral and posterior margins reflected in dorsal direction to form bounding wall; posterior margin deflected dorsally and anteriorly to form short cowl, subconical cup thus suggesting *Keyserlingina* in form.

Brachial valve exterior with 3 lateral and 1 anterolateral lobes on each side of deep median lobe. Exterior smooth.

Pedicle valve interior with wide lobes forming vallum and defining form of brachial valve; vallum angular in section and steep-sided; vallum bounding anterior lobes, meeting usually at point posterior of midvalve into short and stout median ridge, slightly excavated where it faces anterior margin. Hinge narrow, straight, usually poorly visible under cowl; adductor muscle strongly oblique, narrow, elongate, and with outside margin thickened and elevated, inner margin less thickened, position variable, distal end reaching as far anteriorly as posterior end of median ridge, but commonly much shorter.

Brachial valve interior with small ears on cardinal extremities and small, eccentric cardinal process. Lobes and shell body moderately deep; median ridge low and obscure.

MEASUREMENTS (in mm).—

|            | length | maximum<br>width | hinge<br>width | height |
|------------|--------|------------------|----------------|--------|
| USNM 701-d |        |                  |                |        |
| 150701a    | 15.0   | 19.6             | 2.8            | 4.0?   |
| 150701e    | 14.0   | 16.0             | 2.6            | 5.0    |
| 150701h    | 17.7   | 16.0?            | ?              | 7.0    |
| 150701-l   | 12.8   | 16.8             | ?              | 4.0    |
| 150701o    | 10.0   | 16.7             | 1.8            | ?      |
| 150701p    | 16.6   | 16.9             | 2.0            | 6.0    |
| 150701q    | 16.0   | 18.5             | 2.2            | 7.0    |
| 150701r    | 12.6   | 17.0             | ?              | 6.0?   |
| USNM 701-l |        |                  |                |        |
| 150702     |        |                  |                |        |
| (holotype) | 28.2   | 19.5             | ?              | 13.0   |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 4–8 of P. B. King).

LOCALITIES.—USNM 701, 701c, 701d, 701-l, 713h, 718e, 721g, 727e.

DIAGNOSIS.—*Pseudoleptodus* with elevated marginal rim around the exterior of the pedicle valve and a small cowl posteriorly to produce an irregular cone.

TYPES.—Holotype: USNM 150702; figured para-

types: 150700a, b, 150701e, g, h, 153650a–k, 153652a–h, 153653, 153654a; measured paratypes: 150701a, e, h, l, o–r; unfigured paratypes: 150701a–g, i–r, 153654b, c.

COMPARISON.—*Pseudoleptodus conicus* may be easily separated from *P. getawayensis* Stehli and *P. granulatus*, new species, because these two species are very strongly granulate on the exterior of the brachial valves and have granulate tissue in the intervallar parts of the inlobes. All parts of the pedicle valve of *P. getawayensis* and *P. granulatus* not covered by the brachial valve are granulate. The only other species resembling *P. conicus* is *P. guadalupensis* Stehli, but this is a much narrower and more elongate species. Internally the two species are also readily distinguished by the strongly oblique nature of the lobes of *P. guadalupensis*. These are much more oblique than those developed at the anterior of *P. conicus*.

DISCUSSION.—This species is fairly common at USNM 701d, 721g, and 727e, where it occurs with *Striatifera* and numerous sponges in typical biohermal assemblages. The specimens show a variety of sizes, but many of them are incomplete, the thin posterior attachment ends having been broken from the cones. A few specimens are shown in position attached to *Striatifera*, *Diplanus*, algal surfaces, and the cellular face of fenestellid bryozoans. As usual with attached shells, it is difficult to define a normal shape, the form that a specimen living under optimum conditions would develop. The length of the cowl is variable from nonexistent to moderately long. When the cowl is long, the shell produces a well-formed but irregular cone.

*Pseudoleptodus cucullatus*, new species

PLATE 130: FIGURES 9–12

Moderately large for genus, irregularly cowled; apical attachment fairly large. Exterior wrinkled; profile flattened at apex, but main body of shell perpendicular to surface of attachment and gently convex. Interior with long, narrow, strongly sheathed diductor scar. Vallum latilobate, nearly complete, obscure anteriorly, forming 3 outlobes and 1 incipient anterior lobe; median lobe latilobate for nearly entire length, narrow, with subparallel sides.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 721u.

MEASUREMENTS (in mm).—Holotype: length 20.3, width 17.6, hinge width 3.4, height 12.0, cowl length 6.0?

DIAGNOSIS.—Well-cowled *Pseudoleptodus* having oblique lobes; circumvallate.

TYPES.—Holotype: USNM 153642a; unfigured paratypes: 153642b, c.

COMPARISON.—This species is most like *P. guadalupensis* Stehli in profile, outline, and habit of growth, but it differs in being a much wider form. It also suggests *P. conicus*, but it differs in being shorter and rounder and in having fewer lobes.

### *Pseudoleptodus getawayensis* Stehli

PLATE 130: FIGURES 18–34

*Pseudoleptodus getawayensis* Stehli, 1956a:312, pl. 41: figs. 2, 5, pl. 42: figs. 1, 3.

Pedicle valve moderately large, attaining length of 30 mm; subconical outline but usually irregular, with variable cowl. Attachment surface small, apical, usually forming rough inset scar. Exterior marked by strong interrupted concentric wrinkles.

Pedicle valve interior with 4 lateral lobes, usually stout, generally irregular but with median 2 usu-

ally extending farthest laterally. Outlobes broad, branched distally in some specimens and with floor within vallum thickened and rounded. Inlobes usually narrow, with vallum elevated and space within vallum thickened and strongly granulose. Median lobe solid for one-fourth to one-half its length, divided near midvalve, and height of walls diminishing distally from point of division. Vallum anteriorly indistinct, but, although low, appearing to be complete. Muscle scar moderately long, strongly sheathed. All parts of valve not enclosed by vallum strongly granulose.

Brachial valve with 4 moderately wide lateral lobes and 1 short anterior lobe; median 2 lobes with greatest lateral extent; median cleft deep, occupying usually about half the valve length, moderately wide, and narrowly rounded proximally; posterior shell half of body, moderately convex, and depressed longitudinally by a narrow, shallow sulcus representing anterior filling of cleft. Surface strongly and fairly coarsely granulose. Posterior margin forming smooth incurved triangular area, representing joint for hinge movement.

Brachial valve interior with small, spreading cardinal process with scarcely any shaft developed; lateral ears strong and demarcated by prominent diverging ridges; median ridge low, variably developed. Lateral lobes moderately deep, in some specimens with raised lines parallel to margins.

#### MEASUREMENTS (in mm).—

|                          | length | maximum width | hinge width | height | cowl length |
|--------------------------|--------|---------------|-------------|--------|-------------|
| AMNH 512 (=USNM 728)     |        |               |             |        |             |
| AMNH 279341:2 (holotype) | 24.6   | 31.0          | 7.2?        | 8.8    | 6.0?        |
| USNM 150704a             | 32.0   | 27.6          | 8.0         | 12.0   | 6.7         |
| USNM 150704b             | 16.8   | 21.0          | 5.0         | ?      | ?           |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—Getaway: AMNH 512, 519, USNM 728, 732.

DIAGNOSIS.—Thick-shelled, granulose *Pseudoleptodus* of large size with narrow inlobes and 4 lateral lobes.

TYPES.—Holotype: AMNH 279341:2; figured paratype: AMNH 27934:1; figured hypotypes: 150704b, 153637a–e; measured hypotypes: USNM 150704a, b.

COMPARISON.—This species is readily recognized by its large size and strongly granular extralobal

surface. It suggests *P. granulosus*, new species, but that species is much smaller, with a more evenly developed vallum and less strongly conical form. It differs from *P. guadalupensis* (Stehli) in its less elongate form, more robust shell, and less oblique lobes.

DISCUSSION.—As with most of these cementing forms, this is a rare species. The Guadalupe Mountains residues produced four fairly complete pedicle valves and about 25 well-preserved brachial valves. This valve was unknown to Stehli (1956). One of the larger pedicle valves in the USNM collection does not preserve the muscle scars, but it is a worn

valve and it is likely that this structure did not survive its rough treatment. Except for this, the specimen is typical of *Pseudoleptodus*. Most of the brachial valves do not preserve the cardinal process in good condition. This appears to have had little or no development of the shaft, and the myophore is fairly spread laterally.

***Pseudoleptodus? giganteus*, new species**

PLATE 130: FIGURES 6–8

Known from brachial valve only; large, with length and widest part nearly equal; shell body short and narrow; shell divided into unequal halves by deep median split extending posteriorly for about 0.7 valve length; lobes uneven, extending anterolaterally, 3 on left side and 4 on right. Lobes moderately wide with strong concentric growth lines. Surface, in addition to growth lines, finely papillose.

Interior with valve body shallow but lobes moderately deep; body with low median ridge and small, eccentric cardinal process, lobe margins elevated.

MEASUREMENTS (in mm).—Holotype (USNM 150720): length 29.2, maximum width just anterior to midvalve 32.1, hinge width 5.0.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703.

DIAGNOSIS.—Large, multilobed, with narrow hinge and 3–4 wide lobes.

TYPES.—Holotype: USNM 150720.

COMPARISON.—No other known species except *P. grandis*, new species, approaches this one in size, but the brachial valve of *P. grandis* is smooth.

DISCUSSION.—We believe this specimen to belong to *Pseudoleptodus* because it is fairly concave in lateral profile, suggesting that it fitted inside a conical pedicle valve. The exterior is finely granulose. This is not a good argument for generic affinity, but several of the *Pseudoleptodus* species are so ornamented.

The hinge of this species is very narrow, but it shows the cardinal process well. Like other species of *Pseudoleptodus*, this is slightly pushed laterally (toward the observer's right) and is bilobed, one lobe, the left one, being less developed than its companion. The shaft is short and reaches an-

teriorly to a low median ridge that extends to a cleft in the valve. The margins of the lobes are moderately incurved, but they are not strongly thickened as in some species.

***Pseudoleptodus grandis*, new species**

PLATE 133: FIGURES 12–19; PLATE 183: FIGURES 2–10;  
PLATE 189: FIGURE 6

Large, cowed, transversely elliptical in outline, widest near middle; sides narrowly rounded; exterior wrinkled. Attachment surface variable, usually broad and substantial.

Pedicle valve interior with 3 lobes defined by incomplete vallum in pervivallate stage. Lobes varying from latilobate to narrowly angustilobate. Median lobe solidiseptate in posterior but narrowly latilobate anteriorly. Inter and extra vallar surfaces smooth. Diductor muscle, short, narrow, and strongly sheathed.

Brachial valve trilobate and externally smooth. Lobes shallow, but with moderately elevated rims. Cardinal process small, eccentric; median ridge low.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cow length |
|------------|--------|---------------|-------------|--------|------------|
| USNM 737w  |        |               |             |        |            |
| 153567a    | 31.5   | 40.6          | 6.0         | 13.7   | 16.8       |
| (holotype) |        |               |             |        |            |
| USNM 732c  |        |               |             |        |            |
| 153646a    | 28.4   | 31.0?         | 6.8         | 10.3   | 5.0        |
| USNM 742b  |        |               |             |        |            |
| 154525a    | 15.6   | 26.0          | 5.0         | none   | none       |

STRATIGRAPHIC OCCURRENCE.—Word Formation (lens between USNM 706b and the Appel Ranch Member).

LOCALITIES.—USNM 732c, 737w, 742b.

DIAGNOSIS.—Large *Pseudoleptodus* with smooth exterior and extra-vallar areas and strongly conical form in the adult.

TYPES.—Holotype: USNM 153567a; figured paratypes: 153567b, c, 153646a–c, 154525a; unfigured paratypes: 154525b–d; measured paratypes: 153646a, 154525a.

COMPARISON.—This is the largest species of the genus thus far found in a complete specimen. It resembles *P. getawayensis* Stehli in its cowed form, but it differs in being smooth, in having wide loops, and in its advanced pervivallate condition. It differs from *P. giganteus* in having a smooth brachial valve.

*Pseudoleptodus granulosus*, new species

PLATE 132: FIGURES 15-21

Normal size for genus, subcircular in outline, and attached by most of ventral surface, but variable, some specimens attached for only part of ventral surface and being gently to moderately concave.

Pedicle valve interior with narrow, straight hinge; visceral region defined by irregular elevated vallum forming 2 lateral and 1 anterior lobes. Vallum united medially to form elevated central reentrant. Extra vallar areas strongly granulose, granules narrowly rounded and elevated. Diductor scar narrowly elongated and with marginal thickenings, outside strongest and forming half sheath.

Brachial valve variable, irregularly lobed, shape depending on substrate to which pedicle valve attached. Lobes generally narrow but expanding distally. Surface strongly pustulose like that of extra-vallar areas of pedicle valve.

Interior with small, eccentric cardinal process; central part with low median ridge. Margins of lobes thickened.

MEASUREMENTS (in mm).—Holotype (USNM 150714b): length 13.4, maximum width 15.8, hinge width 2.4, height?; paratype (USNM 150714c): length 10.8, maximum width 12.7, hinge width 2.8, height 3.4; paratype (USNM 150714a): length 11.5, maximum width 12.0, hinge width 2.5, height?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (base).

LOCALITY.—USNM 728f.

DIAGNOSIS.—Flattened to subconical with interlobal areas and the exterior of the brachial valve strongly granulose and with strongly granulose and strongly elevated granules.

TYPES.—Holotype: USNM 150714b; figured paratypes: 150714a, c.

COMPARISON.—The strong granulation on the exterior of the brachial valve and in the extravallar spaces makes it necessary to compare this species with two others only. Relationship to *P. getawayensis* Stehli is indicated, but this Guadalupean form is much larger, has a better formed conical pedicle valve, and a more numerous lobated brachial valve.

Relationship to "*Poikilosakos*" *variabile* Wanner and Sieverts (1935) is also indicated because this is a strongly granulose form that probably had a low conical pedicle valve when complete. The Ameri-

can species differs in having the muscle scar narrower and more completely sheathed, the coarsely granular parts of the pedicle valve in the extra-vallar areas, whereas the opposite is true of the Timor species; *P. granulosus* has fewer lobes on the brachial valve.

DISCUSSION.—This is a very rare species, the collection consisting of three pedicle valves and four brachial valves, two of the latter being juveniles. The granules on the younger parts of the brachial valve are so elevated in two of the specimens that they are in the category of spines.

*Pseudoleptodus guadalupensis* (Stehli)

PLATE 128: FIGURES 1-5; PLATE 131: FIGURES 1-42;  
PLATE 188: FIGURES 4-14

*Adriana?* *guadalupensis* Stehli, 1956a:312, pl. 41: figs. 1, 4, 6, 8.

Large for genus, generally elongate and forming incomplete cup; attachment area small and apical and occupied by shell body; anterior side generally longer than posterior part, which forms cowl of varying length over hinge region. Exterior surface marked by concentric growth lines and fairly strong growth wrinkles.

Interior with vallum complete or incomplete and forming lobes of varying width but usually crowded together and narrow. Lobes usually 3 lateral and 1 anterior. Lobes extending anterolaterally at low angle (20°-45°) to median lobe or indentation. Median lobe long with narrow interspace, in some cases closing anteriorly as well as posteriorly, but in others continuing to margin after interruption. Diductor scar long and slender, generally well sheathed.

Brachial valve smooth externally and with strong angular bend at beginning of lobation; lobes generally 4 in number, 3 lateral and one anterior; lobes generally narrow. Interior with characteristic eccentric cardinal process.

MEASUREMENTS (in mm).—

|          | length | maximum width | hinge width | height | hood length |
|----------|--------|---------------|-------------|--------|-------------|
| AMNH 475 |        |               |             |        |             |
| 150718a  | 26.0   | 18.0          | ?           | 12.3   | 9.0         |
| 150718b  | 28.3   | 20.9          | ?           | 17.7   | 14.5        |
| USNM 736 |        |               |             |        |             |
| 150717a  | 13.4   | 14.6          | 2.4?        | 10.5   | 5.0         |
| USNM 731 |        |               |             |        |             |
| 150715a  | 21.0   | 9.7           | 3.4         | 10.4   | ?           |

DIAGNOSIS.—*Pseudoleptodus* forming misshapen cowed cups with narrow lobes inside the pedicle valve and lobes of the brachial valve steeply inclined anterolaterally.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader, and Lamar members), Capitan Formation.

LOCALITIES.—Hegler: AMNH 635, USNM 731, 740c, 740d, 732a; Pinery: USNM 725n, 733, 736; Rader: USNM 725f, 740a, 740i, 740j; Lamar: USNM 728r, 728s; Capitan: AMNH 475, USGS 7404, 7417, 7612.

TYPES.—Figured hypotypes: USNM 150715a, 150717a, b, 152622a, 153651a, c-h, 153659a-c, 153660a-c, e-g, 154524a-d; measured hypotypes: 150715a, 150717a, 150718a, b.

COMPARISON.—This species is not externally granulose, and, therefore, it need not be compared to *P. nodosus*, new species, *P. granulatus*, new species, and *P. getawayensis* Stehli. It is like *P. conicus*, new species, in having a smooth shell, but this is the only similarity because it is a much more slender shell, which has a longer cowl. Furthermore, the interior of the pedicle valve is distinguished readily by the strong obliquity of the outlobes and, consequently, also by those of the brachial valve.

DISCUSSION.—This species presents some features of interest not usually seen in the genus. The manner of growth is unusual. Specimens are cemented by a small portion of the umbonal region, usually 5 to 10 mm. When the animal has attained the requisite growth for good solid attachment, the anterior part bends away from the substrate at approximately a right angle and the anterior part grows away from the attached portion. The posterior part develops a cowl to protect the hinge region. This cowl is of varying length, and the degree of its development determines the form of the shell. Specimens with long cowls develop fairly complete cups. Most of the specimens do not retain any evidence as to the substrate, but two specimens are attached to narrow strips of bryozoa.

Several of the specimens are fairly strongly elongated and have modified the lobes. In *Poikilosakos* these are usually latilobate, but in this species they are variable but generally angustilobate. In many specimens the lobe opening outward is more

elevated at the curve and is moderately excavated.

The median inlobe is also of interest. At its posterior end, where the valve is flat, it is a high and angular ridge, but it opens anteriorly with the change of direction to form two closely spaced ridges almost parallel to each other. In some specimens these remain latilobate to the anterior, where they disappear, but in one specimen the ridges join and stop to appear again a little farther anteriorly to form a narrow ellipse near the anterior margin. In this same specimen some of the lateral ridges join distally to close the lobe to the exterior.

Although the complete brachial valve has not yet been found, fragments and the nature of the visceral lobes give a clue to the form of this valve. Generally the loops are moderately to strongly oblique and extend anterolaterally. Usually three oblique lobes may be counted, with a shorter one extending anteriorly, to make four. The brachial valves are slender and delicate. Another feature is a right angle bend near the shell body. This is due to the right angle bend between the place of attachment and the upright shell.

One specimen (USNM 150715a) is worthy of special mention because of its great elongation and the effect this had on the brachial valve. The specimen is 21 mm long, 7 mm wide at midvalve and about 8 mm deep just anterior to the place of geniculation. The septal ridges show no lobation, and the brachial valve would have been two long lobes separated by a narrow gash between them.

As previously mentioned, the brachial valve of this species was undoubtedly fragile. No complete or perfect specimen has been found, but several imperfect valves, mostly of the rear end or body of the shell, have the eccentric and small cardinal process observed in other species of *Pseudoleptodus*. Another feature of interest in them is the strong angle of geniculation at about the point where lobation begins, a result of the upright living position.

### *Pseudoleptodus lepidus*, new species

PLATE 132: FIGURES 3-14

Medium size for genus, wider than long, transversely elliptical in outline. Attached by posterior half of surface, anterior and sides lifted at strong



angle from surface attachment. Elevated part of shell thin.

Pedicle valve interior with narrow, straight hinge; visceral region defined by strong anterior and posterior vallar ridges, but lateral manifestation of vallum not strongly thickened; lobes irregular, 2-3 per side, anterior one bifurcated. Median ridge narrow to moderately wide, posteriorly excavated. Diductor scar narrowly sheathed on each side but not enclosed dorsally; outside wall of muscle scar larger.

Brachial valve variable, lobes narrow to wide; cardinal process small; surface marked by fine granules.

MEASUREMENTS (in mm).—Holotype: length 13.0, maximum width 20.0, hinge width 4.0, height 5.5?; paratype (152623a): length 11.2, maximum width 16.0, hinge width 4.0, height?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITY.—USNM 719z, 727j.

DIAGNOSIS.—Transversely elliptical *Pseudoleptodus* with the anterior and lateral half elevated from the surface at a large angle.

TYPES.—Holotype: USNM 152623f; figured paratypes: 152623a-c; measured paratype: 152623a; unfigured paratypes: 152623d, e.

COMPARISON.—This species in its *Poikilosakos*-like habit is different from most other species of the genus. *Pseudoleptodus getawayensis* Stehli and *P. guadalupensis* (Stehli) are larger, more conical, and much more of the anterior part of the shell is extended above the substrate. The new species from the Word Formation, *P. nodosus*, is similar in growth habit, but the lateral lobes are much stronger. *Pseudoleptodus granulosus*, new species, also has a similar habit, but more of the shell is attached to the substrate and the shell surface between the loops is strongly granulose.

DISCUSSION.—Six specimens of *P. lepidus* are known, no two of them alike. Two of the pedicle valves are similar, but the third was aborted anteriorly by the adherence of another oldhaminidine. Two of the brachial valves have wide channels, but the third has narrower interior channels and they are thickened marginally, whereas the others are not. It is possible that more than one species is involved.

### *Pseudoleptodus nodosus*, new species

PLATE 127: FIGURE 1

Known only from pedicle valve, small, wider than long, transversely elliptical in outline; exterior smooth. Interior with narrow hinge area; diductor muscle sheathed and extending at almost right angle from hinge; 2 lobes separated by latilobate ridge, part of incomplete vallum, which is low laterally and posteriorly. Median lobe septate posteriorly, but latilobate anteriorly and fairly wide at front. Posterior and extravallar areas marked by nodes or pustules. No cowl.

MEASUREMENTS (in mm).—Length 11.6+, width 22+, hinge width 4.6, height 6.0?

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank Member).

LOCALITY.—USNM 713.

DIAGNOSIS.—Transversely elliptical *Pseudoleptodus* with fine pustules or nodes in the extravallar areas.

TYPES.—Holotype: USNM 150707.

COMPARISON.—This species has the finest nodes of all the nodose or granulose species.

### *Pseudoleptodus primitivus*, new species

PLATE 130: FIGURES 2-4

Small for genus, subelliptical in outline, broad surface attached to substrate, posterior and lateral parts forming callus flap on substrate, then growing upward away from substrate. Profile low or moderate cone, depending on height of flap.

Visceral region of interior surrounded by strong vallum forming fairly high wall and defining two broad lobes; vallum medially indented and uniting near midvalve to define deep indentation forming anterior tube; hinge straight, narrow, and anteriorly notched. Diductor scar large, subflabellate, not laterally surrounded by shell tissue, but thickened along anterior margin.

Brachial valve unknown.

MEASUREMENTS (in mm).—Holotype (USNM 150713a): length 6.2, maximum width 8.2, hinge width 1.6, height?; paratype (USNM 150713b): length 7.3, maximum width 9.8, hinge width 1.4, height 3.0.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (top 15 feet of bed 2 of P. B. King).

LOCALITY.—USNM 701.

DIAGNOSIS.—*Pseudoleptodus* of small size, 2 lateral lobes, and a tubular anterior median inlobe.

TYPES.—Holotype: USNM 150713a; figured paratype: 150713b; unfigured paratype: 150713c.

COMPARISON.—This species differs from all other described forms in having a strongly tubular anterior inlobe, two broad smooth lobes anterolaterally, and a wide muscle scar.

DISCUSSION.—This is the simplest species of the genus found in the Glass Mountains. In its bilobed form it suggests a young specimen and also suggests "*Cardinocrania*" Waagen. The three specimens are distinctly conical and thus indicate a post-infantile stage. They are unlike *Cardinocrania* in the possession of the eccentric diductor muscle. The muscle scar, however, is somewhat broader distally than those seen in other species. The vallum is thin and delicate but strongly elevated. Of special note is the median lobe, which is roofed over for at least half its length to form a tube.

### *Pseudoleptodus* Indeterminate Species

PLATES 130, 131, 132, 139, 183

Some "species" are represented by too few specimens to be identified as known species or to be described as new species. Brachial valves are found more commonly than pedicle valves because brachial valves can be transported more easily than the cemented pedicle valves. Consequently, the indeterminate "species" are generally specimens of brachial valves. These specimens are assigned tentatively to *Pseudoleptodus* because it occurs more frequently than *Poikilosakos*.

### *Pseudoleptodus?* species 1

PLATE 139: FIGURES 12-14

This species has a narrow hinge and an extremely short body. The lobes are stubby and wide. Two lateral lobes appear on each side, and a short anterior lobe is indicated. Internally a sharp, low median ridge extends posteriorly from the proximal end of the median indentation for slightly more than half the distance to the hinge. The cardinal process is eccentric but poorly formed. A suggestion of adductor scars appears just posterior to the proximal end of the median ridge. The

specimen is 14.2 mm long, 17.3 mm wide (but is not complete in this direction), and has a hinge 4.6 mm wide. The specimen is from the lower Bone Spring Formation at AMNH 46.

TYPES.—Figured specimen: USNM 153639.

### *Pseudoleptodus?* species 2

PLATE 139: FIGURES 1, 2

This is a short-bodied form, but it contrasts with the preceding in having two narrow lateral lobes and a narrow anterior one. Internally a ridge appears in the concave side of the lobes. The specimen is 12.6 mm long and 14.4 mm wide, but it is incomplete in this direction. The hinge is 4.5 mm wide, but it appears incomplete. The specimen comes from the Bone Spring Formation at AMNH 591.

TYPES.—Figured specimen: USNM 150710.

### *Pseudoleptodus?* species 3

PLATE 130: FIGURES 13-17

This species is represented by several brachial valves and four fragments of pedicle valves (USNM 150711a, b). It is not certain that these belong together, but the combination is possible. The fragments of the pedicle valve indicate a broadly expanded shell with low concavity. The exterior is marked by numerous fine concentric wrinkles. One specimen shows part of a posterior irregular scar of attachment, indicating that the species probably was posteriorly attached and anteriorly free. Inside the shell are broadly rounded lobes that are widely spaced. Two lateral and one anterior lobes are indicated. The vallum of the median lobe is well separated and more strongly elevated than the lateral ones. The hinge and muscle scar have not been seen.

Six brachial valves are variable, but they indicate a narrow-hinged form with short body. Two lobes extend laterally and one anteriorly. The lateral extent of the lobes is variable, but two specimens indicate a long first lobe but shorter lateral and anterior ones. In one specimen the reverse is true, and in the others the lobes have been damaged. Internally the cardinal process is eccentric and minute and the median ridge is thread-like. One specimen of the six has broader lobes

than the others. Satisfactory measurements cannot be obtained, but the length of the brachial valve as indicated by USNM 150711b is 12 mm and the maximum width about 22 mm. The hinge of this specimen is 3.6 mm wide. This lot is from the Hegler Member of the Bell Canyon Formation at USNM 731.

TYPES.—Figured specimens: USNM 150711a,b; unfigured, described specimens: 150711c-j.

*Pseudoleptodus?* species 4

PLATE 132: FIGURES 1, 2

This species is represented by four brachial valves (USNM 150712a-d) having two lateral and one anterior lobes, the lateral lobes separated by wide reentrants. The shell body is moderately long, but the hinge very narrow. The median reentrant or slot is wide. The surface is smooth. Interior of body and lobes is moderately deep, and no median ridge is developed posterior to the reentrant. No cardinal process was observed. The specimens are from the lowest part of the Cathedral Mountain Formation just above the conglomerate at USNM 708u.

TYPES.—Figured specimen: USNM 150712a.

*Pseudoleptodus?* species 5

PLATE 130: FIGURE 5; PLATE 131: FIGURES 43-45

This is a large species represented by three specimens (USNM 152624a, b from USNM 721u and a small one (USNM 152625) from USNM 703a<sup>1</sup>. The one complete specimen of the larger group is transversely elliptical in outline, about 13 mm long by 21 mm wide. The shell is distorted, but the lobes have a strongly elevated vallum. The median lobe is narrow, low, and not strongly excavated. The small specimen from 703a<sup>1</sup> is 8 mm long by 12 mm wide. It is thin shelled and the left side forms a smear on the spiriferoid, to which it is attached. The anterior margins of both specimens are elevated above their substrate. All of the lobes are rudimentary. The specimen is clearly a young one.

TYPES.—Figured specimens: USNM 152624a,b; 152625.

*Pseudoleptodus?* species 6

PLATE 130: FIGURE 1

This is a very small specimen of indefinite outline because the pedicle valve can scarcely be distinguished. The brachial valve is in place, 6.6 mm long and 9 mm wide. It is bilobed, one lobe extended laterally and the other anteriorly. The anterior of the pedicle valve is elevated above its substrate. The specimen is from the Cathedral Mountain Formation (Wedin Member) at USNM 714w.

TYPES.—Figured specimen: USNM 153641.

*Pseudoleptodus?* species 7

PLATE 139: FIGURES 15, 16

Two brachial valves, both probably immature are all that are known of this species. They are wide bilobed, the lobes short and stubby, one extending laterally, the other anteriorly. A mere trace of the cardinal process remains, but a thread-like median septum is present in both. The specimens are from the Road Canyon Formation, USNM 724c.

TYPES.—Figured specimens: USNM 153640a,b.

*Pseudoleptodus?* species 8

PLATE 183: FIGURES 15-17

Known only from the pedicle valve, which is a small cowled form, wider than long, with a small base of attachment. Measurements in mm are: length 13.4, width 15.0, hinge width 4.0, height 6.6, cowl length 3.0. Diductor muscle slightly sheathed, short, and confined to the attachment area. Vallum incomplete, latilobate; median inlobe latilobate, widely open anteriorly. 3 outlobes. Exterior wrinkled and smooth. Word Formation at USNM 737b.

TYPES.—Figured specimen: USNM 153568.

*Choanodus*, new genus

[Greek *choane* (funnel) + *odous* (tooth)]

Small to medium size for lyttoniids, irregularly cowled with small to moderate-sized apical cicatrix of attachment; anterior side longest but with generous cowl over posterior side. Exterior surface concentrically wrinkled.

Pedicle valve interior with toothlike commonly corrugated projections on each side of, and just anterior to, hinge, bearing lateral flanges of brachial valve hinge. Diductor scar asymmetrical, large. Inlobes thick, papillose, latilobate in young, but angustilobate in adults; outlobes with thickened, rounded ridge bounded by narrow channel; posterior edge of earliest formed lobe undulated; early lobes occasionally branched; lobes ranging from 3 to 8. Median lobe solidiseptate, strongly elevated, and divided anteriorly into 2 narrow ridges.

Brachial valve irregular, with margin of first lobes undulated posteriorly and commonly branched on one side or other; hinge with lateral flanges; interior with lobed but eccentric cardinal process without shaft; median ridge prominent; lobes with margins deflected in ventral direction.

TYPE-SPECIES.—*Choanodus irregularis*, new species.

DIAGNOSIS.—Cowled Poikilosakidae having shelf-like articulating processes in the pedicle valve and articulating flanges in the brachial valve and thick angustilobate lobes.

COMPARISON.—This genus suggests a conical *Poikilosakos*, but it differs in having more elaborate and advanced lobation. It also lacks the open troughlike median lobe and has a larger, more flabellate, unsheathed asymmetrical adductor scar. The cardinal process of the brachial valve is more prominent and shows myophore surfaces.

This genus also suggests *Keyserlingina* Tschernyschew in the exterior form of its pedicle valve, but the interior details appear to be different. The brachial valve of *Keyserlingina* as figured by Fredericks (1927a:86) has posterior humps on the earliest lobes and also branched lobes. The hinge region of *Keyserlingina* is small, and no indication of lateral flanges is given. Furthermore, views of the pedicle valve given by Tschernyschew (1902, pl. 42: figs. 14–17) and Licharew in (Sarycheva, 1960, pl. 42: fig. 8) indicate that it had an open latilobate divided median lobe, not yet closed to form a solid median ridge. The Russian *Keyserlingina* in this respect is more like conical *Poikilosakos* than is *Choanodus*.

This genus differs from *Pseudoleptodus*, which it resembles in its conical form and robust solidiseptate lobes, in the different type of hinge, the more

strongly anterolateral direction of the lobes, and the narrow outlobe channels.

DISCUSSION.—This genus is recognized readily by the stout shells and conical form, some of the cones being almost symmetrical. The attachment area is generally small, but it is substantial enough for sure fixation. The initial stage is generally flat, but the shell is soon deflected at a high angle from the surface of the substrate. *Choanodus* is commonly attached to *Eolyttonia*, but it is also attached to a variety of other shells, including some of the smaller productids such as *Xenosteges*.

The interior of the pedicle valve of this genus is unusual for its hinge and the thick angustilobate-to-solidiseptate lateral vallum. The hinge is unique and is an important element of the structure in the pedicle valve. This consists of conical, toothlike bodies on each side of, and just anterior to, the lateral ends of the slitlike hinge. These bodies suggest an articulate process, but they have their posterior face flattened, and, in well-preserved specimens, the process is minutely corrugated. This face receives a flat surface of the lateral articular nubs of the brachial valve. This makes for a more rigid articulation than usually is found in the Poikilosakidae.

The muscle scars are preserved clearly in all of the specimens, but several individuals show a large asymmetrical scar on the right side of the interior. This is broad and subflabellate and usually thickened strongly at the anterior ends.

The lobes of the pedicle valve are noteworthy for the robustness of their development. The inlobes of the younger valves are composed of two ridges (angustilobate) moderately compressed but forming a thick medially depressed ridge. With increasing age the median depression is filled in and the ridge becomes solidiseptate, a rounded and thick partition bounding the outlobes. The inter-ridge channels are marked by a narrow, rounded ridge separated from the side of the inlobes by narrow channels. This creates a series of low ridges bounded by higher ones. Most of the ridges are directed anterolaterally rather than laterally and convex anteriorly as is usual in most of the Lyttoniidae. Some inlobes are so thick and strong that they dominate the posterior half of the shell.

The brachial valves, as in other poikilosakids, have the posterior margin of the posterior lobe,

which may be the longest one, marked by several posteriorly directed lumps. This feature was seen also in *Pseudoleptodus*. It is a common occurrence for one or more of the lateral lobes to bifurcate, especially the posteriormost one. Occasionally adjacent lobes fuse.

*Choanodus anomalus*, new species

PLATE 183: FIGURES 11-14

Small, elongate oval in outline; conical but with short cowl. Exterior with strong, concentric wrinkles. Interior with *Choanodus* articulation consisting of 2 articulating nubs bounding sockets; median ridge thick, low posteriorly, highest in posterior third. Posterior one-fourth of median ridge solidiseptate but anterior three-fourths angustilobate; anterior half of median ridge decreasing in height but widening anteriorly. Each side of median ridge with 6 wide inlobes, broadly angustilobate and highest anteriorly, depressed area of inlobes papillose. Grooves between lobes shallow but marked medially by longitudinal adventitious thickening.

MEASUREMENTS (in mm).—Holotype (USNM 153569a): length 18.3, maximum width 14.6, hinge width?, height 6.8, cowl length 3.5.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 721u.

DIAGNOSIS.—Small, conical, elongate *Choanodus* with thick and strongly papillose inlobes.

TYPES.—Holotype: USNM 153569a; unfigured paratypes: 153569b,c.

COMPARISON.—This species differs from *C. perfectus*, new species, in its smaller size and its imperfect conical form. It is unlike *C. irregularis*, new species, in its more elongate form, shorter cowl, and wide, papillose inlobes.

*Choandus irregularis*, new species

PLATE 133: FIGURES 8-11; PLATE 134: FIGURES 6-12;  
PLATE 135: FIGURES 1-41; PLATE 162: FIGURES 8-10

Shell small, forming irregular cones attached at apex by small to medium-sized cicatrix; cones broadly open when viewed from dorsal side; cowl usually short; valves circular to roundly elliptical in outline. Exterior with concentric wrinkles and

with interseptal spaces strongly and coarsely pustulose.

Pedicle valve interior with narrow hinge and strong anterior, shelflike teeth; initial lobes usually with 1 or more prominent posterior humps; 1 or more lobes occasionally branched to produce asymmetrical arrangement. Lobar channels consisting of 2 parallel grooves separated by narrowly rounded median thickening; median lobe solidiseptate, not reaching hinge region, usually thick in median region but decreasing in height anterior to midvalve and dividing into 2 weak ridges near front margin. Diductor scar usually difficult to see, but, when visible, usually broadly flabellate and with anterior marginal thickened rim. Inside of cowl strongly papillose.

Brachial valve with straight hinge and thin lateral articulatory flanges; lobes thin, irregular, posterior lobes with 1 or more humps on posterior side; 1 or more lobes branched, branching not symmetrical. Surface strongly pustulose.

Brachial valve interior with small, bulbous, eccentric cardinal process; median ridge moderately strong but low; lobes with thickened and elevated margins; trough running parallel to margins at base of elevations; trough botnded on inside by low, thin, elevated line parallel to margin; area between thin lines faintly pustulose. Adductor scars indistinct.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 702un |        |               |             |        |             |
| 150832a    | 14.1   | 18.8          | 3.3?        | 8.2    | 6.2         |
| USNM 703b  |        |               |             |        |             |
| 150835a    | 10.8   | 12.6          | 2.3         | 3.9    | 1.4         |
| 150835b    | 12.0   | 17.0          | ?           | 6.4    | 4.6         |
| 150835c    | 13.8   | 16.0          | 2.9         | 5.6    | 3.5         |
| 150835d    | 15.4   | 16.7          | 3.3         | 6.9    | 4.2         |
| 150835e    | 15.1   | 18.9          | 2.7         | 4.5    | 3.0         |
| 150835f    | 19.7   | 21.3          | 3.1         | 9.6    | 4.1         |
| USNM 714w  |        |               |             |        |             |
| 150840     | 19.0   | 21.8          | 3.9         | 10.4   | 11.0        |
| USNM 702   |        |               |             |        |             |
| 150827a    | 12.3   | 17.5          | 3.0         | 6.7    | 5.6         |
| 150827b    | 13.1   | 19.0          | ?           | 9.0    | 6.1         |
| 150827c    | 19.0   | 17.6          | ?           | 9.5    | 8.8         |
| 150827d    | 18.4   | 25.4          | 2.6?        | 9.2    | 6.7         |
| 150827e    | 22.4   | 28.7          | 3.5         | 9.3    | 4.2         |
| 150827f    | 11.5   | 15.0          | 3.3         | 6.4    | 4.4         |
| 150827g    | 17.2   | 17.9          | 3.0         | 8.6?   | 4.8         |
| 150827h    | 24.0   | 25.7          | ?           | 14.0   | 8.3         |



STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Cibolo Formation.

LOCALITIES.—Cathedral Mountain: USNM 702, 702a, 702a<sup>1</sup>, 702b, low, 702un; 703, 703a<sup>1</sup>, 703b, 703bs, 708, 712o, 714w; 717e, 721u, 726o, 726u, 726x, 733m, AMNH 500, 500H, 500L, 500X, 658; Cibolo: USNM 725v.

DIAGNOSIS.—*Choanodus* of moderate size with greatly thickened interlobar spaces.

TYPES.—Holotype: USNM 150838; figured paratypes: 150727, 150826a, c–e, 150827c,e,f,g; 150828a, d, 150830, 150835b,e,f, 150840, 150842, 153604, 153605, 153606, 153645; measured paratypes: 150832a, 150835a–f, 150827b–h; unfigured paratypes: 150826b, 150827b,d,e, 150828b,c, 153835a, c, d.

COMPARISON.—No other species of this genus is closely comparable to *C. irregularis*. Fragments of another species were taken from the Bone Spring Formation in Black John Canyon in the Sierra Diablo. This is larger, and the inloops are much thicker and stronger than those of *C. irregularis*; however, the form of the hinge and other details of the shell are not known. Detailed comparison with *C. perfectus*, new species, the only other species known well enough to describe, is given under that species.

DISCUSSION.—This species is best developed and perhaps most abundant in the zone of *Institella* at the base of the Cathedral Mountain Formation. It ranges just above this zone, however, and is fairly common in the *Eolyttonia* beds just above it in the Split Tank area and in the vicinity of the Old Word Ranch.

### *Choanodus perfectus*, new species

PLATE 133: FIGURES 20–24; PLATE 136: FIGURES 1–17;

PLATE 137: FIGURES 1–20

Large, irregularly conical in outline, cones tending to become more regular with increase in size; anterior side slightly longer than posterior one, which extends as long cowl over posterior of pedicle valve. Exterior marked with fine growth lines and irregular concentric wrinkles.

Pedicle valve interior with 12 to 14 lobes in largest specimens; articulatory processes small, located on both sides of hinge. Initial lobes usually small and convex toward anterior; lateral lobes more direct. Septal ridges thickest in posterior, decreasing in thickness and height anteriorly; interseptal callosity low rounded ridge bounded on each side by grooves running parallel to septal ridges. Median ridge slender and moderately high in posterior half, dividing into 2 low ridges at midvalve in some specimens, but farther forward in others.

Brachial valve externally granulose, with slender lobes convex toward anterior or extending nearly straight laterally. Axial region thick, reaching to about midvalve, there deeply cleft. Articulating flanges thick, not usually well preserved. Interior with eccentric, short and thick cardinal process and low median ridge. Interior of lobes deep, with thickened margins bearing trough at base and bounded by thin parallel line running around lobe longitudinal lobes, bounding median cleft deep and marked just inside of inner margin by strong carinate ridge running from angle of cleft to anterior extremity.

#### MEASUREMENTS (in mm).—

|                    | length | maximum width | hinge width | height | cowl length |
|--------------------|--------|---------------|-------------|--------|-------------|
| USNM 702un         |        |               |             |        |             |
| 150846a            | 58.7   | 49.1          | ?           | 28.0   | 9.0         |
| 150846b (holotype) | 40.0   | 41.2          | ?           | 20.6   | 17.5        |
| 150846c            | 34.0   | 40.5          | 4.0?        | 17.0   | 6.0         |
| 150846d            | 42.8   | 39.4          | ?           | 23.7   | 16.7        |
| 150846e            | 38.5   | 55.0          | 7.0         | 27.7   | 22.5        |
| 150846f            | 44.0   | 40.6          | ?           | 20.5   | 19.8        |
| 150846g            | 22.3   | 25.0          | ?           | 14.2   | 12.1        |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Cathedral Mountain Formation (Wedin Member).

LOCALITIES.—Bone Spring: AMNH 504, 591;

Wedin: USNM 700–1, 700x, 714w, 727p; Cathedral Mountain: USNM 702, 702b, 702un, 703a<sup>1</sup>, 703b, 708, 708u, 721u, 726u, 735b.

DIAGNOSIS.—Large *Choanodus* with numerous lateral lobes.

TYPES.—Holotype: USNM 150846b; figured paratypes: 105845a–c, 150846a, d, e, 153607 a, b, 153608, 153609, 153610, 154647; measured paratypes: 150846a, c–g; unfigured paratypes: 150846c, f, g.

COMPARISON.—In general form this *C. perfectus* is similar to some species of *Eolyttonia* such as *E. pocillata*, new species, and *E. diabloensis* (Stehli). Both of these differ from *C. perfectus* in having thicker shells, wider and stouter lateral lobes in the brachial valve, and a different type of hinge in the pedicle valve. *Choanodus irregularis*, new species, also has stouter shells than *C. perfectus*, and also it has more posterolaterally directed lobes and stronger, thicker inlobes in the pedicle valve, but it has a lesser number of lateral lobes and is a smaller shell. It is also strongly papillose in surfaces outside of, and between, the lateral lobes.

DISCUSSION.—*Choanodus perfectus* is a rare species known only from the zone of *Institella*. It forms nearly complete and often nearly perfect cones attached by a small apical part to productids, bryozoans, lyttoniids, and other substantial objects. This is a much larger species than *C. irregularis*, with more numerous lateral lobes but generally a more delicate shell. The cowl in adults is wide and flaring and may match the anterior side in length. The hinge is like that of the genotype, the tooth-like projections often prominent and corrugated to receive the articulating flanges of the brachial valve. They are not visible clearly in all specimens, especially those that were dead and waterworn when buried and fossilized.

The development of the lobes is not entirely like that of *C. irregularis*, and the posterior lobes are seldom as massive; they form lobes with the convex side anteriorly directed, whereas, in the other species, the lobes extend anterolaterally. In the young the lobes form a vallum that is closed anteriorly in some specimens. With growth the inlobes are compressed and narrowed, in some cases becoming completely closed and solid in the proximal part adjacent to the median channel, but remaining open distally toward the lateral margins.

The lateral lobes of the brachial valve are very closely crowded. In the posterior third the lobes are fairly elevated and at least partly solid, but anteriorly they are raised only slightly and the

appearance of fairly strong interseptal ridges complicates the pattern.

The median or axial canal is narrow and, in the adult, is unusually so. It is almost completely occupied by the median ridge, which is fairly strong. This extends nearly to the hinge, is thickest in the midregion and is divided in the anterior third in many specimens.

The hinge of this species appears to be exactly like that of the type-species, but no unequivocal example showing the asymmetrical adductor scar was seen. This scar was difficult to see in the type-species; thus, it is not surprising that it was not detected in a larger and thinner-shelled species. This fact, however, does cast some doubt on the generic affinities of the species. It was placed in *Choanodus*, rather than in *Eolyttonia*, which it strongly resembles, because of the nature of the hinge.

The brachial valve of this species is characterized by its thick but short axial region, the strong anterior cleft generally extending posteriorly beyond midvalve, and the delicate, very slender lateral lobes. It is also characterized by a very short initial lateral lobe without the posterior undulating margin. One specimen from USNM 714w, however, has a moderately long initial lobe with several posterior lumps characteristic of *Choanodus*.

### *Sceletonia*, new genus

[Greek *skeleton* (mummy)]

Medium size for Oldhaminidina, incompletely conical, posterior with short cowl and small attachment surface. Exterior with radial lobes corresponding to lobation of interior.

Interior strongly ridged with median ridge having 3 lateral, oblique ridges on each side. All ridges granulose on crests. Troughs occupied by lower median elevation. Musculature asymmetrical, with well-defined muscle mark on (observer's) right.

Brachial valve with subradial lobes ornamented by strong concentric growth lines and strong pustules; interior with narrow straight hinge having small ears; visceral region moderately large, with low, median ridge and obscure adductor scars. Cardinal process uneven with myophore lobes, one on observer's right being larger. Channels of lobes deep, narrow, and with strong, elevated outer border and lower inner one.

TYPE-SPECIES.—*Sceletonia crassa*, new species.

DIAGNOSIS.—Poikilosakidae with thick inner lobes visible on the exterior and with an asymmetrically bilobed cardinal process.

COMPARISON.—The thick internal ridges of this genus set it apart from all others except *Choanodus*, which also has fairly thick internal septa lobes; however, *Sceletonia* differs in having a less conical form, shorter cowl, and less laterally curving septa. Furthermore, the brachial valves are quite different, that of *Sceletonia* having very direct rays, a stronger cardinal process, and much wider lateral lobes.

DISCUSSION.—The few specimens of this genus now known are unique among the Oldhaminidina and are unusual for their exterior as well as interior details. The exterior reflects the lobation of the interior, the lobes of the exterior corresponding to the troughs of the interior. The dichotomy of the median lobes is well displayed. That this is not a freak of preservation is shown by specimens from the Sierra Diablo, as well as from the Glass Mountains, having the same external lobation. The troughs between the lobes are occupied by concentric lamellae that undulate more or less strongly over the whole exterior. Strong concentric undulations, as well as fairly strong pustules, also appear on the exterior of the brachial valve.

On the interior, two sets of ridges appear, one thick, conspicuous, and strongly elevated set, and, between these, a lower set that occupies the center of the troughs. Longitudinally the center is marked by a strong median ridge that runs from near the apex to the front margin. It is undivided, not excavated. This divides the median channel, from which three strong ridges diverge at an angle of about 45°. These create four oblique channels. Medially each channel bears a low ridge that evidently is related to the central channel of the brachial valve lobes.

The brachial valve is fairly solid, with a thick shell having strong marginal rims. The cardinal process is interesting because it is bilobed, although the lobes are unequal in size. It does not have a well-defined shaft. The visceral region has traces of adductor muscles, but they are not separable into their parts. The channels all extend from the visceral region and are marked by the marginal rim, a narrow submarginal channel separated from the main channel by a low ridge. The median

channel undoubtedly corresponds to the medial low ridges of the main channels of the pedicle valve.

The genus is assigned to the Poikilosakidae because of the primitive character of the channels and ridges and the asymmetric musculature.

This peculiar genus is known only from the Skinner Ranch Formation in the Glass Mountains and from the lower part of the Bone Spring Formation of the Sierra Diablo. This rare occurrence is a confirmation of our correlation of the Skinner Ranch and the lower Bone Spring.

### *Sceletonia crassa*, new species

PLATE 138: FIGURES 1-34; PLATE 139: FIGURES 3-10

Fairly large with thick shell and strong inner ridges; transversely elliptical in outline, greatest width near midvalve; sides narrowly rounded; anterior broadly rounded. Attachment scar small; cowl short. Exterior marked marginally by 4 lobes on each side of median line; inner 2 lobes uniting at about one-third length toward posterior, resulting unified lobe uniting with third lobe at midvalve, this one extending to apex. Fourth or outer lobe extending direct from margin to beak. Exterior with concentric, raised ridges unevenly distributed but best developed anteriorly.

Interior as defined for genus.

MEASUREMENTS (in mm).—Paratype (USNM 151328d): length 24.0, maximum width 33.7, hinge width 7.6, cowl length 6.8, depth 10.2; holotype (USNM 151328h): length 24.3, maximum width 33.6, hinge width 12.6, cowl length 7.3, depth 9.0.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Dugout Mountain and Sullivan Peak members), Bone Spring Formation.

LOCALITIES.—Dugout Mountain: USNM 732d, 732e, Sullivan Peak: 722l, 727a; Bone Spring: AMNH 591, USNM 725c.

DIAGNOSIS.—Subconical, strongly ridged *Sceletonia*.

TYPES.—Holotype: USNM 151328h; figured paratypes: 151328a, d-g, i, j, 152626, 153587a, b, 153588a, b, 153589a, b; measured paratype: 151328d; unfigured paratypes: 151328b, c.

COMPARISON.—No other species of the genus is known.

DISCUSSION.—Sixteen specimens of this species were taken in the Glass Mountains, and nine occur in the collections from the Sierra Diablo.

### Family LYTTONIIDAE Waagen, 1883

Usually large, conical or subconical with numerous lateral septa in pedicle valve and numerous lobes in brachial valve. Lateral septa originating from poikilosakid vallum: angustivallate to fragmentivallate. Muscle marks symmetrical when present; myophragm present in some genera. Brachial valve pinnate to sievelike, usually with bilobed or quadilobed cardinal process.

DISCUSSION.—The prevailing form assumed by members of the Lyttoniidae is that of a cone, uncommonly a complete and symmetrical cone, but, nevertheless, usually some modification of a cone. The symmetrical cone is best exemplified by the genus *Pirgulia* Cooper and Muir-Wood from the Sosio Limestone of Sicily. This is a long, slender cone, pointed at the apex but narrowly elliptical at the open end. These shells attain large size, having a length of 135 mm, a width at the aperture of 75 mm and an apical angle of about 30°. They probably lived attached by their apex for at least part of their life, but such large shells could not have retained vertical stability when they attained full adulthood (Rudwick and Cowen, 1968).

Another completely conical form is *Eolyttonia gigantea*, new species, from the Glass Mountains. This is not a tapering cone like *Pirgulia*, but it has a broadly rounded base with a fairly broad surface of attachment. This could quite easily have been attached throughout its life. Fairly complete cones are produced by other species, and some forms of *Eolyttonia* Fredericks form broad shallow cones.

Some genera that normally have broad, shallow, or misshapen cones may produce deeply conical specimens because of unfavorable growth conditions in a cluster. This is true of a specimen of *Coscinophora* Cooper and Stehli (see Plate 182: figures 35, 36), which was so crowded that its only direction of growth after a certain stage was aperturally. The cowl, unable to grow laterally, expanded toward the anterior and thus produced a deep cone, suggesting that of *Eolyttonia gigantea*.

Specimens of *Eolyttonia* often form broad, open cones, found in such species as *E. circularis*, new species, which is in the form of a broad, shallow dish. Others have misshapen cones in which the anterior side has grown more rapidly than the cowl, producing a broad and oblique aperture.

In contrast to the cones are the flattish shells of

*Collemataria*, new genus, *Petasmaia* Cooper and Grant, and *Leptodus* Kayser, in which there is no cowl, but a flap grows posteriorly, thus destroying any resemblance to a cone. Exceptions occur in these genera, however, in which the circumstances of growth force the flap to become cowl-like and to grow opposite to its normal direction. Such misshapen cones are produced as an aberrancy. *Petasmaia* commonly attached to crinoid stems or other small, round objects to produce broad flat expansions quite unlike the more normal conical genera.

Inside the pedicle valve the hinge of the various genera seems not to show any exceptional characters, and nothing like the hinge of *Choanodus* was seen. Considerable variation occurs in the lip overhanging the hinge in many species, but the pattern in all of them seems the same.

The most interesting and important features of the pedicle valve are the lateral loops and their development into septal ridges. The septa are variable with the age of the animal and within the same specimen. Only rarely is it possible to generalize on the type of septum. Genera such as *Keyserlingina* and early *Eolyttonia* have the septa in the form of in-and-out wide loops, forming a vallum that may be complete around the entire visceral area or may be incomplete anteriorly. With growth and with geological age the loops are compressed in a direction parallel to the long axis of the shell. Therefore, in early youth some of the genera have lateral septa that bear a groove down the middle (latilobate to angustilobate). This is characteristic of the type-species of *Eolyttonia* and its synonym *Paralyttonia*. This was so prominent in some of the Russian representatives of these genera that lateral septa so grooved are said to be in the *Paralyttonia* stage (pervivallate). With continued age the median groove is eliminated and the lateral septum becomes narrowly rounded (solidiseptate). This type of septum is commonly seen in the larger and geologically younger, more anterior or more adult parts of many specimens (septivallate stage).

The final stage (terminivallate) is that seen in *Oldhamina*, in which the lateral septa are thin and delicate and have a knife-edge crest (anguliseptate). This has been termed the "oldhaminoid" stage in allusion to its common occurrence in the Pakistan genus. As will be explained below, this character does not always denote an evolutionary end mem-



ber, but that is also dependent on other features of the shell, which culminate their development in *Oldhamina*.

It is a common but exasperating occurrence to find all of these stages of lateral septal development in one and the same specimen, not only from certain genera, but also from most of the genera that have developed large shells. The type of lateral septum definitely depends on age, but it also may depend on shell shape. Specimens that have developed unusual depth or convexity from youth to old age develop lateral septa having the characteristics of the oldhaminoid stage (anguliseptate). Evidently *Oldhamina* produces a majority of lateral septa in the anguliseptate condition, because the shell is generally deeply concave in its normal development.

Many lyttoniids are distorted considerably because of their attached form of growth; consequently, some are deeper than normal, while others have become strongly concave in lateral profile. Such a reversion of the normal inner surface also produces profound effects on the lateral septa. The normal lateral septum dips posteriorly at a moderate angle and commonly overhangs the interseptal trough in the front or in an anterior direction. Shells that are convex inward may have lateral septa that are vertical or overturned. In such shells the posterior surface dips anteriorly and overhangs the interseptal space behind, or posterior to, it, and the lower surface dips anteriorly. This condition is not frequent, but it does illustrate the profound effect the curvature of the shell has on the form and development of the lateral septa. The dependency of the form of the lateral septum on the shape of the shell severely limits the value of these structures in classification and recognition of genera.

Another variation seen in the septa is the transition laterally along the same lateral septum from the rounded solidi or anguliseptate condition ("*Leptodus*" stage) to the grooved angustilobate condition ("*Eolyttonia*" stage). This too is rare in occurrence, but it adds to the confusion.

Spasmodic branching occurs in the outlobes or lateral septa of the various genera. In the Poikilosakidae this is common and often leads to inequality of the two sides of the brachiopod. This has helped the view that the Poikilosakidae nor-

mally have unequal valves. Inequality of the right and left halves is abnormal for brachiopods, and we believe that it is abnormal, even though frequent, for the Poikilosakidae. Members of the Lyttoniidae also produce branched lateral septa, although the occurrence is less frequent than in the more primitive family. The branching takes place on either side of the axis or on one side only. It usually results in distortion of the lateral septa posterior and anterior to the branching one. Another abnormality seen outside of *Coscinophora* is the breaking up of a lateral septum into a row of beads or dashed ridges (the moniliseptate condition). This too may occur at any part of the shell.

*Coscinophora* is unique among the Lyttoniidae in having most of the septal rows moniliseptate. These generally behave like the septal ridges of other genera in their variation. They may be long or short, steep or gently inclined, and in the younger or larger part of the shell, where there seems to be some instability, they may have solidiseptate lateral septa.

The anterior part of the lyttoniid shell appears to be a place of instability. Here many aberrations of the lateral septa take place. They often change their direction from lateral to anterolateral or anterior as the case may be. They are also known to make sweeping curves that throw the normal regularity into chaos. Beading of the lateral septa may take place here, and so faintly are the septa raised above shell floor level that it is common for them almost to disappear.

The course of development of the lateral septa was first worked out by Fredericks and, except for minor details, appears to be as he stated. Later observers have corroborated the general scheme, which is also borne out by our study of the Texas lyttoniids. The young of the Lyttoniidae and the adults of the Poikilosakidae have in their earliest stage a simple ringlike ridge bounding the visceral region, herein called *vallum*. In the early stages of both families the vallum is indented anteromedially. With advancing age, indentations appear on the sides in a number according to the genus and species. These indentations produce *inlobes* and *outlobes* of the vallum, which still retains its continuity. The anteriomedian indentation produces a strong and deep inlobe. The outlobes are part of the visceral region, whereas the inlobes par-



take of the strong granulation of the lateral part of the shell outside the visceral region. The vallum thus defines the form of the brachial valve, which fits snugly within the confining wall. *Poikilosakos* represents the adult stage of this early condition. It is a lobate wall, having an equal number of lateral lobes indenting the visceral region and a long median lobe indenting the anterior and all surrounded by a continuous wall or vallum ("flange" of Watson, 1917). Evolution affects the vallum in two ways: (1) it disrupts its continuity by increasing the number of lateral lobes anteriorly; and (2) it gradually compresses the wall of the lateral lobes into a single ridge and the median inlobe into a median ridge. In the *Poikilosakidae* the vallum remains fairly complete except for the anterior in advanced genera, and, in the *Lyttoniidae*, it loses its continuity except in extremely young stages, and the number of lateral lobes or septa is increased enormously.

The lateral septa retain a trace of the inlobe condition well after they have been compressed into a lateral septum. In many septa that are narrowly grooved, the material in the groove, bounded by ridges, is granulose, i.e., pseudopunctate, like that of the side of the shell margining the ends of the septa. This is clearly shown in thin sections and is proof of the evolution of the lateral septum. In septa distorted in position because of accidents of attachment, the intervallar space, i.e., the space or groove between the two ridges, is also distorted, being narrowed or widened. Lateral septa tilted abnormally forward have the intervallar groove widened, the posterior side appearing as a ridge well down the slope of the surface of the lateral septum. Where lateral septa are tilted posteriorly, the intervallar or grooved part appears on the anterior side.

The modification of the lateral septa in conformity with the varying contours of the pedicle valve have been explained above. Other modifications appear, but these seem to be common to all genera and have no particular significance in taxonomy. A noticeable modification that commonly alters the interior appearance of the pedicle valve is the interseptal callosity that appears as a prominent ridge in the interseptal channels between the lateral septa. These ridges may be low, or, in the anterior region, they may equal or exceed the

height and strength of the lateral septa. The interseptal ridges originate at the distal extremities of the interseptal channels in the earliest formed (oldest) part of the shell. With growth these appear farther and farther anteriorly and penetrate laterally toward the median channel. In the youngest part of the shell toward the front margin they commonly occupy the entire interseptal channel from lateral margin to median channel. They create a closely ridged or corrugated surface usually occupying from one-fourth to one-third of the valve length.

The interseptal ridges undoubtedly restrict the interior because the lateral lobe of the brachial valve overlies them closely. If the brachial valve was immovable, as has been contended, the interior of the anterior third would have been nonfunctional.

Another feature of the lateral septa and the adjacent interseptal channels is the striation of the septum on its posterior (and often anterior) face and the concomitant striation or pitting of the interseptal channel. The striation of these surfaces is brought about in the adventitious deposit laid down in the interseptal space on each surface of the lateral septum. Generally the fluting of this material is strongest and most regular on the posterior face of the interseptal ridge. This results in a serration or fluting of the anterior margin of the lateral lobe of the brachial valve that is inserted against the edge of the striated layer. In interseptal thickening where a ridge is produced, the fluting takes the form of a row of pits on the anterior side of the posterior lateral septum bounding an interseptal channel and the posterior side of the anterior lateral septum. Long sloping lateral septa or extremely elevated ones have the striation most pronounced. The floor of interseptal areas is marked also by irregular pits like those seen in a variety of pseudopunctate shells such as many *Strophomenidina* and *Productidina*. This fluting may have accommodated setae along the lateral grooves.

The median ridge divides the central or axial channel into two parts. Its development is like that of the lateral septa. It originates as an inlobe or indentation of the middle of the front margin of the vallum. Throughout the history of the *Poikilosakidae* this median inlobe maintains its

open character and, in some cases, forms a median chamber. In the Lyttoniidae, on the other hand, lateral pressure originating posteriorly results in a squeezing of the median vallum to form a narrowly open or grooved ridge, then a ridge divided and open anteriorly from midvalve, and finally a completely closed, single ridge.

Variation of the median ridge within species and individuals is common. It varies in height and strength, in the location at which it divides anteriorly to form an open lobe, and in its continuity. Commonly in *Collemataria*, but more rarely in other genera, the ridge may become anteriorly discontinuous, moniliseptate, and form a row of beads or dashes with a concomitant fenestration of the median axial region of the brachial valve. This is so prominent in some specimens that the Termiers created the genus *Gubleria* for it. It is also common in *Leptodus* (= *Lyttonia*) as remarked by Huang (1932:89). It is in reality an evanescent feature without generic value except in *Coscino-phora*, where all or nearly all of the lateral septa and the median ridge are moniliseptate.

The median septum served to close the median groove when the brachiopod was at rest or in alarm. The slit of the anterior axial region of the brachial valve fits snugly against, or over, the median ridge—in many genera, just posterior to the point where the ridge divides.

A SURVEY OF THE GENERA OF LYTTIONIIDAE.—This will help to crystalize the above remarks and the characters used in the separation of the genera.

*Adriana* DeGregorio (1931:29). The poor sketches of lyttoniids offered by DeGregorio do not permit a proper assignment of this genus to either family of the Lyttoniidae. It was mentioned above, under the Poikilosakidae, that this genus cannot be placed in that group because it is impossible to see the family characters in it. This lack of family character information makes it impossible to place the genus in the Lyttoniidae as well. The conical form of *Adriana* is more suggestive of lyttoniid structure than it is of poikilosakid affinities, but this is a tenuous argument for such placement. The correct assignment of this genus will have to await reexamination of DeGregorio's specimens or topotype material if such can be identified.

The figures also suggest a possible relationship of *Adriana* to algal forms such as *Irma* and *Imperia*

and not to the Brachiopoda. Williams', et al. (1965: H520, figs. 3a, b) reconstruction is very doubtful.

*Cardinocrania* Waagen (1885:745). This genus has not been adequately described or figured, and the interior of the brachial valve is unknown. The pedicle valve is provided with a hinge like that of the Lyttoniidae or perhaps a very young *Richthofenia*. Just in front of the hinge there is a broad anteriorly excavated plate bearing muscle scars. The anteromedian region is indented, and a short median ridge extends posteriorly for a short distance. The brachial valve according to Schuchert (1939, pl. 1: fig. 1) fits over the hollow, surrounded by the thickened margin, and is externally papillose. This is all that is known of the valve.

The Salt Range specimens differ from those figured by Wanner and Sieverts (1935:6, figs. 1, 2) in having muscles on both sides of the muscle region, whereas those from Timor have muscles only on the right side. Wanner and Sieverts' specimens suggest the young of *Pseudoleptodus* rather than *Cardinocrania*. Schuchert (1939) thought that *Cardinocrania* represented the young of *Richthofenia*, which might be true of his specimen, but Muir-Wood and Cooper (1960:137) believed that this genus was the young of *Leptodus* rather than that of *Richthofenia*. They pointed to the similarity between the hinge arrangement of *Cardinocrania* and *Leptodus* and to the bilobed form of the latter. The hinge region of *Cardinocrania* is unlike that of young *Hercosia* of the Glass Mountains. Muir-Wood and Cooper (1960), having been misled in this respect by the figures of Wanner and Sieverts, were mistaken in their view that the musculature of *Cardinocrania* was a single scar like that of *Poikilosakos*. The proposition that *Cardinocrania* is the young of *Leptodus* is more in accordance with the structure of the two genera because intermediate forms between the two are not known. We regard *Cardinocrania* as a junior synonym of *Leptodus*.

*Chaoella* Licharew (1931:161). This is a small conical genus that Licharew (1932:103) placed in the synonymy of *Keyserlingina* a short time after he described it.

*Collemataria*, new genus. This name is applied to Lyttoniidae that are generally flattish, expanding anteriorly, have a posteriorly growing callus flap, and the hinge and cowl margins coinciding

in the adult. No muscle scars have been seen in the pedicle valve. This genus is similar to *Leptodus*, but it lacks well-defined muscle scars and lateral muscle ridges, and the lateral septa are mostly in an advanced pervivallate to septivallate stage.

*Coscinophora* Cooper and Stehli (1955:469). This genus is usually a broadly open cone, but it varies in form to that of a small cup. It is unique for the degeneration of the lateral septa and median ridge into rows of beads or dashes (fragmentivallate). The brachial valve is a perforated plate, thickened medially.

*Gubleria* Termier and Termier (1959:241). This genus is based on fragments of the anterior of a lyttoniid in which the anterior cleft has been restricted to a row of elliptical holes corresponding to fragmentation of the median ridge into a moniliseptate condition. This phenomenon occurs in individuals of other genera such as *Leptodus*, *Collemataria*, *Pirgulia*, and *Eolyttonia*. It is an individual, rather than a generic, character. We regard *Gubleria*, therefore, as a probable synonym of *Leptodus*.

*Keyserlingina* Tschernyschew (1902:55, 473). This is a rare and poorly understood genus because only the pedicle valve is known. All illustrations show it to be a primitive or an immature form, because it has a nearly complete vallum (circumvallate stage) and the median lobe is open from the anterior margin nearly to the hinge area. We are not able to corroborate Tschernyschew's description of the hinge region with its delthyrial structure. Nothing like this was seen in any of the early lyttoniidae in North America. *Keyserlingina* is most similar to Stehli's *Pseudoleptodus* in its conical form and circumvallate condition, but an eccentric muscle scar has not been described or figured in *Keyserlingina*. *Choanodus*, new genus, is similar in its conical form and internal structure, but it has a solid, well-advanced median ridge in the pedicle valve and a less deeply cleft brachial valve. At any rate, *Keyserlingina* is a primitive form, as it occurs in the "Schwagerina" Limestone of the Urals and the Trogkofel beds of the Alps, corresponding to part of the late Pennsylvanian or Wolfcampian of North America.

*Leptodus* Kayser (in Richthofen, 1883:161 = *Lyttonia* Waagen, 1883:395, 396) (Plate 191: figures 11–15). Examination of one of the type specimens

of *Leptodus* indicates the identity of this genus with *Lyttonia*. The specimen is 31 mm long and 39 mm wide, evidently a fairly young individual. It shows eight lateral lobes and a broad median region. Most of the shell is exfoliated from the specimen. The shell is strongly pseudopunctate and shows a median ridge. No evidence of a cowl could be seen, and the small apex suggests a broad, spreading apical region like that of the Salt Range "*Lyttonia*" (= *Leptodus*). On the right side, just anterior to the apex, crossing the second lateral lobe, there is a calcareous ridge suggesting a septal plate that bounds the muscle area. No evidence of muscle scars was seen. Huang (1932:87, pl. 8: figs. 4a, b) described and figured a specimen referred to this species. This clearly has affinities with the Pakistan form.

This specimen, figured by Kayser (1883, 4:161, pl. 21: figs. 11, 11a), is designated as the type of the species. The specimen is in the collections of the Geologischer-Paläontologischer Museum, Berlin, East Germany. The specimen comes from the Upper Permian in Loping, China.

*Leptodus nobilis* Waagen (Plate 191: figures 8, 9) is a species from Pakistan with numerous lobes. Seldom silicified, it afforded an opportunity to figure the nature of the lobes in relation to the secondary or fibrous shell layer.

*Loxophragmus*, new genus. This name is proposed for small transversely elliptical attached shells in the terminivallate stage.

*Oldhamina* Waagen (1883:395, 403). This is one of the best known and most distinctive of the Lyttoniidae. It is characterized by a fairly strongly convex lateral profile and deeply concave pedicle valve. This odd shape helps to account for the terminivallate stage of the lateral septa, which are thin, strongly oblique, and knife-edged (anguliseptate). The posterior attachment is folded posteriorly and rounded in such a way that it suggests the adult life of the shell was spent unattached from the substrate.

*Oldhaminella* Wanner and Sieverts (1935:232). Information on this genus is based wholly on the discussion and figures given by Wanner and Sieverts. The shells are strongly convex, attached, wider than long, and consist of three to four lateral septa, most of which appear to be in the pervivallate stage. According to Wanner and Sie-

verts, the outer half of the lateral septa are in the state mentioned, but the inner half are *Oldhamina*-like (anguliseptate). The ridgelike sides of the lateral septa are separated by a fairly wide band of secondary shell. Perhaps the most conspicuous feature of the genus is its musculature and the presence of two muscle ridges on each side of the median ridge.

This genus is based on two pedicle valves that are attached to crinoid stems and are engulfed partly by tissue from the stems growing over them. The specimens suggest to us immature forms, perhaps the young of *Lyttonia catenata* described in the same publication (Wanner and Sieverts, 1935). This species is attached to crinoid stems, but its musculature is not now known. The generic evaluation of the muscle ridges is a problem that cannot be settled here because only two specimens are known that have them and a similar arrangement has not been seen in other lyttoniids. This is a probable synonym of *Leptodus*.

*Paralyttonia* Wanner and Sieverts (1935:207). These are small shells attached by their entire ventral surface like *Poikilosakos*. The septal ridges are in the lativallate state, i.e., with broad, open lobes, all directed anteriorly. The posterior lobe margin is undulated as in the Poikilosakidae, but the muscle scars in the pedicle valve, as indicated by Wanner and Sieverts (1935, pl. 6: fig. 4b), are bounded by lateral ridges and are separated by a median myophragm, thus making them symmetrical. This is contradicted by another specimen assigned to this species and illustrated by figure 7b on the same plate. The specimen is anomalous because it has an eccentric muscle on the left side of the valve, unlike any other poikilosakid or lyttoniid. This may be due to imperfect preservation, but it is difficult to be sure from an illustration. The brachial valves are anteriorly digitate and granulose exteriorly, but their interior is not known.

The probable symmetrical nature of the muscle scars, in spite of the *Poikilosakos*-like appearance of the shells, indicates relationship to the Lyttoniidae. The minute size and primitive character of the septal lobes again suggests a possible immature stage of *Leptodus*. If this is an adult form, it must be ranged with *Rigbyella* in the Lyttoniidae.

*Petasmaia* Cooper and Grant (1969:10). This name is applied to large, circumvallate to septival-

late, rapidly expanding, and generally flattish lyttoniids that have strong lateral ridges bounding the muscle area and lateral septa predominantly in the latilobate to solidiseptate states. These shells commonly attached to crinoid stems or to other narrow objects, but they are not confined to this type of substrate.

*Pirgulia* Cooper and Muir-Wood (1951:195). This name is used for elongate and narrowly conical Lyttoniidae having lateral septa in the pervallate to septivallate stages. The slender, nearly symmetrically conical form is unique in the family.

*Rigbyella* Stehli (1956a:310). This genus is similar to *Paralyttonia*; its type-species originally was placed there. It differs from *Paralyttonia* in having a cuplike form. Its musculature is symmetrical, and it is, therefore, referable to the Lyttoniidae.

*Uralina* Schuchert and LeVene (1929:127 = *Uralia* Licharew, 1925:4). A synonym of *Eolyttonia*.

*Vincia* De Gregorio (1930:31). The members of this genus form misshapen cones composed of a long ventral side and a shorter dorsal side in the form of a cowl. The scar of attachment is fairly large, and the lateral septa are in the pervallate to septivallate stages. The genus strongly resembles *Eolyttonia*, which has priority over *Vincia* and probably is a senior synonym.

### Ecology of the Lyttoniidae

The Lyttoniidae were, for the most part, cemented animals. That some of them lived loose on the sea bottom seems evident from the conditions under which they are collected and from their shell anatomy. *Oldhamina* and *Pirgulia* probably lived for a considerable part of their adult life free on the sea bottom, but most of the other genera lived attached.

All of the Poikilosakidae were attached throughout life, and *Poikilosakos* was fixed by its entire ventral surface. The later poikilosakids, such as *Pseudoleptodus* and *Choanodus*, geniculated in a dorsal direction along the lateral and anterior margins to produce a cuplike form. These little cups were fixed strongly to a host, a fact that accounts for the rarity of their shells in the residues. No preference of host by any of the Poikilosakidae was noted.



The conical Lyttoniidae were less strongly cemented to the substrate than the broad, expanding forms such as *Collemataria* and *Petasmaia*. The former, with their large callus flaps, make clusters and small banks like oysters, but the conical forms are often stripped by storms or currents from their moorings. Banks of the conical forms are also made under stable conditions, but they break up more readily than the more tightly cemented species. The latter also are often found loose, tightly cemented to a fragment of their host.

None of the lyttoniid genera seems to have been selective in the type of host to which an individual anchored. *Petasmaia* appeared to thrive on crinoid columns, but this may not have been a matter of selection of substrate. Many specimens were attached to the carinate edge of pelecypods such as *Leiopteria* Hall, a surface that approximates a crinoid stem, but they were also attached to flatter objects. Wanner and Sieverts (1935:248) illustrate their species *Lyttonia catenata* attached to a crinoid stem with the posterior of the *Lyttonia* oriented in an upper position. We believe that *Petasmaia* probably also attached to living crinoid stems but that the orientation on the stem should be opposite to that figured by Wanner and Sieverts. The posterior of the brachiopod should be down, i.e., toward the sea bottom, with the anterior margin facing the crinoid crown. The widely expanded form of these shells, growing rapidly all around the edge of the shell except at the point of attachment, can be explained only by the fact that they must have been free.

Attachment of the lyttoniid spat was so random for most genera that it is no wonder they have such a wide range of form and distortion. *Coscinophora* had broadly open cones, but some, such as specimens USNM 153655c, f, formed complete cones because they were unable to expand normally. The anterior tube of *Collemataria batilliformis*, new species, appears to have been induced by extreme crowding. A small fraction of specimens of all sizes and ages shows this anterior channeling phenomenon. It is thus not an old age character, but it must have been caused by crowding at the anterior end of the shells.

The shape of a shell may be controlled by its host. This is especially confusing in such genera as *Collemataria*, which does not normally have a cowl.

The larva settles on the concave side of a small productid. The valve grows in all directions, but, because of the curvature of the host, the posterior part is forced to grow in an anterior direction. This produces a cowl over the hinge region and a shell form like that of *Eolyttonia*.

In the Glass Mountains, lyttoniids occur in few places in countless numbers. They are most conspicuous in the Split Tank area just above the *Institella* zone at the base of the Cathedral Mountain Formation. Here layers three to four feet thick abound in specimens (Plate 20: figure 3). These suggest that a large colony lived and was partially destroyed at this place. Many specimens are loose and must have been detached from the main mass. A few small clusters can be obtained. In the etching process, it is difficult to hold the larger pieces together; consequently, it is not possible to tell how much of a decalcified piece originally consisted of attached specimens. The field evidence suggests, however, that masses of considerable size, including many individuals, existed on the sea bottom in many places.

The same is true of *Coscinophora*, which forms large colonies or banks in the Road Canyon Formation (Plate 17: figures 3, 4). These occur scattered throughout the formation, but most frequently near the base. Generally the specimens are not connected and appear to have been broken from a large mass. Decalcification of blocks of this material yields some connected clusters that can be held together with care. Generally the clusters collapse when the supporting rock is removed. Evidence points to the fact that loose clusters and masses existed on the sea bottom to form bioherms. An excellent example from the Skinner Ranch Formation is shown on Plate 129: figures 20, 21.

Some biohermal development of lyttoniids exists in the Wolfcampian Neal Ranch Formation. One locality (USNM 722x) produced a small patch of *Eolyttonia* cemented by encrusting algae. These lime-secreting plants are also present in some of the bioherms high in the Cathedral Mountain Formation. Wolfcampian bioherms with lyttoniids are fairly common and, in our experience, occur in the Neal Ranch and Skinner Ranch formations. The Cibolo Formation (Brecciated Zone of Udden) in the Chinati Mountains (USNM 728-1 contains bioherms notable for the large size of the *Eolyttonia*



making up much of their mass. The Word Formation, on the other hand, has not yet revealed bioherms in the Glass Mountains. The lyttoniid occurrences there are usually isolated loose specimens or clusters of two or three individuals. These may have made patches, but they were broken and distributed over the sea bottom to contribute their share to the numerous death assemblages.

The above remarks appear to be true of the lyttoniid occurrences in the Guadalupe Mountains and in the Sierra Diablo as well. No large patches of lyttoniids suggesting bioherms were seen in either area. All of the lyttoniids were taken from death assemblage associations. These regions have been studied only casually, from a paleontological point of view; consequently, more exhaustive exploration may yield some lyttoniid bioherms.

Rudwick and Cowen (1968) discussed the feeding mechanisms of the lyttoniids, suggesting two possibilities. One method suggested is that they fed by bringing in water currents through the slits and out the anterior; the other method is that, by a gentle pulsation of the brachial valve, they produced the entrance of streams of food-bearing water. The feeble cardinal process and musculature, together with the median channel of the pedicle valve, suggest to us the former, rather than the latter, method. The musculature of these animals—what can be seen of it—was not very powerful. In many of the genera with large individuals, the brachial valve, even with the numerous openings in it, would have been fairly heavy.

### Genus *Eolyttonia* Fredericks, 1924

*Eolyttonia* Fredericks, 1924a:25; 1925:63.

Conical to semiconical circumvallate, to septivalate pedicle valves having short to long cowl enclosing hinge area; attachment at apex small to large; surface marked by concentric lines and wrinkles.

Pedicle valve, interior with narrow hinge having thickened overhanging lip and lateral articulating pits; lateral lobes numerous, convex anteriorly, early species and young specimens with well-defined vallum laterally; later species and old specimens with vallum compressed into latilobate to solidiseptate ridges, but with anterior septa ungrooved; in later species grooved septa confined to young, or

sporadically developed in adults. Median ridge variable partially septivallate, usually open anteriorly from midvalve depending on species. Interseptal spaces, especially anteriorly, marked by thickened ridge and commonly strongly pitted.

Brachial valve with lobes convex anteriorly; hinge straight, with small articulating nubs. Cardinal process single shafted, shaft short, and bilobed myophore generally spreading. Median ridge low; valve commonly deeply cleft anteriorly.

TYPE-SPECIES.—*Oldhamina* (*Lyttonia*) *mira* Fredericks (1916:74, pl. 2: figs. 8, 9).

DIAGNOSIS.—Conical Lyttoniidae with latilobate vallum in young stages or early adult species, but with grooved angustilobate or ungrooved (solidiseptate) septa in adult forms or late species; brachial valve with single shafted cardinal process.

COMPARISONS.—*Eolyttonia* has the form of *Keyserlingina* Tschernyschew and *Parakeyserlingina* Fredericks. The former genus is usually small and has only a few lateral lobes, which are defined by a well-formed vallum. Furthermore, it does not have a single median septum, but rather a central posteriorly directed lobe of the vallum, as in the Poikilosakidae. From all that can be gathered from the literature and the illustration of *Parakeyserlingina darvasica* (Tschernyschew), the type-species of *Parakeyserlingina*, the same is true for that genus. Corroboratory evidence is seen in the hypothetical constructions of the brachial valve of *Parakeyserlingina*, which are shown with a median cleft extending almost to the hinge, suggesting that the cleft surrounded an open posteriorly directed median loop of a vallum. If this supposition is true, *Parakeyserlingina* is closer to *Keyserlingina* than to *Eolyttonia*, as stated by King. This supposition is also supported by the synonymizing of *Parakeyserlingina* with *Keyserlingina*, as indicated in Sarycheva (1960:238) and Williams, et al., (1965:H518).

*Eolyttonia* differs from *Collemataria* in the form of the shell and the type of attachment, the latter being fixed at the posterior with a reenforcement of callus and without a cowl. Furthermore, the lateral septa of the pedicle valve of *Collemataria* seldom are grooved medially, and, if they are, it is only in the juvenile stages or sporadically in the adult.

*Choanodus* is strongly conical like *Keyserlingina*,

but it differs from *Eolyttonia* in having an elaborate articulation.

*Eolyttonia* differs from *Leptodus* in the form of the shell and in the lack of muscle marks at the posterior. The method of attachment is dissimilar in the two genera, *Leptodus* being flatter and more expanded anteriorly. *Oldhamina* is much more convex than *Eolyttonia*, is attached differently, and generally has oblique and sharply angular lateral septa (anguliseptate).

DISCUSSION.—*Eolyttonia* is an early name that may be useful for a number of species of Lyttoniidae that hitherto have not been satisfactorily placed. The interpretation given here may not prove satisfactory when the various species are better known from larger collections. The latitude given the name here includes the form of the shell and the interpretation of the development of lateral septa.

The type-species, *E. mira* (Fredericks), appears to be a low, asymmetrical cone, the shell having a long ventral side, but the cowl short. The American species assigned to *Eolyttonia* have shell shapes ranging from like that of the type-species to ones that are complete and almost symmetrical cones. *Eolyttonia fredericksi* (R. E. King) is a species with considerable variation in the form of the shell. The species having the most symmetrical shells is *E. gigantea*, new species, which formed deep cones with a broadly rounded apex and broad openings at the other end. Some of these approach the proportions of a teacup.

The hinge of *Eolyttonia* is like that of *Leptodus*, an overhanging posterior lip that may be strongly swollen. It also has lateral depressions to receive small articulating points on the brachial valve.

The most important feature of *Eolyttonia* that makes it distinctive is the development of the lateral septa. In the young a well-formed and complete vallum can be detected. With growth the anterior walls of the outloops are pressed together to produce narrow latilobate lobes with subparallel walls. But advancing age may compress the lobes still farther until the outlobe becomes angustilobate to solidiseptate, usually with a narrow median depression. This is the condition of the septa in *E. mira* and is the usual condition of the septa in many young forms, although, with growth, the depression along the crest of the ridge may be filled and the septal ridge may have a narrowly rounded

crest. Later species have a majority of the septa with narrowly rounded crest—the most advanced stage for this genus.

*Eolyttonia fredericksi* (R. E. King) is a large species, unique for having a fair portion of its first formed lobes in the young stage in the angustilobate condition. In this species, however, later and more anterior lobes are low, but often fairly widely grooved. In deeper parts of some specimens that are more curved than normal, some septa may approximate the stage seen in *Oldhamina* (anguliseptate), but generally the septa are not so sharply carinate, but they are strongly inclined.

All species of *Eolyttonia* from the Glass Mountains have the septal lobes descending anteriorly in height and widening with the expanding cone. Generally the last few lobes are low, and the ones nearest the front are commonly difficult to discern. Beginning posteriorly and along the distal extremity of the lobes, a low rounded ridge appears between the vallum walls and parallel to them. These ridges extend in successive lobes inward toward the median trough. In the lobes nearest the front they extend from end to end and are often as strongly elevated as the vallum wall. When this takes place, the anterior part of the shell appears to be made of nearly equally spaced, narrow ridges like corduroy. This development is not uniform, but it seems to occur spasmodically within a species. In addition to the transverse parallel ridges, rows of pits appear in the depressions on either side of the adventitious ridges. This feature also is developed spasmodically in the genus, but it appears conspicuously in other genera such as *Collemataria*.

The median ridge is not uniformly developed in all species. In some it is medianly grooved posteriorly and anteriorly, but in most of them it is grooved or open only anteriorly, usually beyond midvalve. The median ridge usually extends to the hinge, but at the posterior it is generally thin and delicate. At the front, after it has divided, the ridges become low and may be difficult to see.

The brachial valve normally is unsymmetrical and anteriorly cleft for varying distances, depending on the condition of the median ridge of the pedicle valve. The hinge is straight and narrow, usually with small points or alae laterally. Internally the hinge is marked laterally by a small triangular area

on each side separated by a low, oblique ridge. The cardinal process has a single shaft of varying length that frequently is distorted, in one valve almost parallel to the hinge. The myophore is bilobed and usually small, but it may be expanded laterally. The cardinal process is usually near the center of the hinge, but many appear slightly off center.

The midline of the brachial valve is generally marked by a median elevation, not developed, or only poorly developed in the young, but more strongly marked to prominent in adult and old shells. At the cleft and anterior to it, a ridge extends parallel to the margin of the cleft. This gives the appearance of two ridges margining the longitudinal lobe anterior to the cleft. The lateral lobes are usually deep, but they may be thickened medially by adventitious shell, beaded on the margins or forming a low ridge. This ridge is parallel to the lobe margins and also to the proximal ends of the lobes at the median trough. Many of the lobes have scalloped margins where the shell is in contact with the pitted interior of a pedicle valve lobal trough.

*Eolyttonia* appears to be characteristic of the Lower Permian. It is common in the Wolfcampian of the Glass Mountains, but rarer in the Leonardian and rare in the Guadalupian. It appears to be commonest in biohermal associations.

### *Eolyttonia catilla*, new species

PLATE 145: FIGURES 1-4; PLATE 157: FIGURES 1, 2

Large for genus, broadly conical in profile with large cowl; broadly elliptical in outline, but variable; cicatrix variable but substantial; surface marked by numerous concentric wrinkles. Known from pedicle valve only.

Interior with about 13 lateral lobes; latilobate to angustilobate; lobes dying out anteriorly, anterior third broad and smooth. Median ridge solidiseptate to beyond midvalve, but angustilobate anteriorly; median ridge low and inconspicuous; hinge narrow.

MEASUREMENTS (in mm).—Holotype (USNM 153584): length 83.0+, width 104.6, hinge width 13.5, cowl length 42.0, height 34.0; paratype (USNM 153583): length 83.0, width 80.7, hinge width ?, cowl length 46.8, height 47.3.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (bed 9 of Cooper = bed 12 of P. B. King).

LOCALITY.—USNM 701c.

DIAGNOSIS.—Gigantic *Eolyttonia* with broad open cones and septa mostly latilobate to angustilobate.

TYPES.—Holotype: USNM 153584; figured paratype: 153583.

COMPARISON.—This species ranks in size with *E. gigantea*, new species, of the Skinner Ranch Formation (Decie Ranch Member), but it differs markedly in having a broad, open cone with the anterior side longer than the posterior. The specimens are like a small, oddly-shaped dish.

DISCUSSION.—These specimens were taken from the same bioherm that produced specimens of *Eolyttonia fredericksi* (R. E. King), but they have an entirely different shape. They do, however, have a very similar stage of development of the lateral lobes to that of King's species.

To have attained such a large size without notable deformation, these forms must have been solitary dwellers.

### *Eolyttonia chaotica*, new species

PLATE 141: FIGURES 1-17; PLATE 142: FIGURES 1-17

Moderate to large, irregular, varying from shallow expansions to moderately deep bowl-like shells, deepest posteriorly, but becoming shallow to flat anteriorly; attachment moderately large, usually with considerable callus in one or more layers; sides strongly curved and elevated in dorsal direction posteriorly, but descending anteriorly; sides and anterior usually well rounded. Surface marked by strong but fine concentric wrinkles.

Pedicle valve interior with about 16 lateral septa in adults, posterior 7 of which are generally fairly elevated and inclined forward, deeply undercut and single-edged (solidiseptate) or grooved (angustilobate) on crest. Septa descending in height anteriorly and strongly ridged or pitted on anterior and posterior surfaces. Interseptal callosities originating on outside of early lobes and growing inward anteriorly and strongly ridged or pitted on anterior and posterior surfaces. Callosities moderately thick and narrowly rounded. Median trough narrow, marked by low median ridge, usually less conspicuous in posterior half, strong medially but becoming flattened toward front end, some specimens with me-

dian groove or dividing to form 2 low, threadlike septa. Hinge narrow with strong posterior lip and with lateral articulating grooves.

Brachial valve with narrow median axis marked by shallow median, longitudinal groove; lateral lobes narrow, about 2.5 mm in anterior-posterior direction; loops not connected distally. Exterior with strong, scattered granules.

Brachial valve interior with small to moderately large eccentric cardinal process; median ridge strong and extending from cardinal process to anterior cleft; lobes shallow and marked by a deep groove and low ridge parallel to all margins; inter-ridge areas roughened and papillose.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 721-o |        |               |             |        |             |
| 150649a    | 49.0   | 49.6          | ?           | 22.0   | 10.6        |
| 150649b    | 49.9   | 53.5          | ?           | 7.0    | 11.0        |
| 150649c    | 49.0   | 58.0          | 9.6         | 24.7   | 20.0        |
| (holotype) |        |               |             |        |             |
| 150649d    | 59.0   | 62.0          | ?           | 30.6   | 18.4        |
| 150649e    | 51.1   | 39.6?         | ?           | 23.0   | 15.2        |
| 150649f    | 61.0   | 51.0          | 10.0        | 21.6?  | 11.0        |
| 150649g    | 53.6   | 56.5          | 8.0         | 18.0   | 9.5         |
| 150649h    | 27.0   | 34.0          | 5.0         | 6.0    | 5.0         |
| USNM 702c  |        |               |             |        |             |
| 150645     | 63.7   | 60.0          | ?           | 20.0?  | 13.5?       |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 702, 702b, 702 low, 702un, 703b, 712o, 726o; Road Canyon: 702c, 703a, 703d, 707e, 719x, 721j, 721o, 721s, 721x, 721y, 723u, 726d, 726z.

DIAGNOSIS.—Advanced *Eolyttonia* with short cowl, 16 lateral, oblique septa, usually obliquely grooved.

TYPES.—Holotype: USNM 150649c; figured paratypes: 150644a, 150649a, b, e, g, i, j, 153619a–e, 153621a, b, 153620, 153622; measured paratypes: 150645, 150649a, b, d–h; unfigured paratypes: 150649d, f, h.

COMPARISONS.—This species is like *E. pocillata*, new species, in profile, outline, and the degree of conical development, but it differs in having a larger adult size and a generally stronger septal development. The septa of *E. chaotica* are usually more strongly fluted.

This species is not as strongly conical as *E. fredericki* (R. E. King) and the septa are in a more

advanced stage, generally having the median grooving of the posterior septa obscure or strongly oblique (angustilobate to solidiseptate).

DISCUSSION.—The strongly developed vallum of young forms of this species indicates clear relationship to *Eolyttonia*, but the species shows definite advancement in the development of its lateral septa in the adult form. The exterior shape of the shell is not unique or unusual, but some variation of the attachment surface leads to confusion in generic assignment. Shells growing on a flat surface tend to be broadly open, but their conical form is generally clear. Others in less favorable positions may have the development of the cowl aborted at an early stage so that the posterior may strongly resemble that of *Collemataria* with its posteriorly spreading callus flap.

Although the exterior of these shells is seldom distinctive, the interior offers more possibilities in detail for separation of species; and although the form and development of the hinge offer no possibilities in this direction, the vallum and septa do. Young specimens ranging up to 25 mm in length have a well-defined vallum with good continuity except at the front, where its course is not clear. Whether or not the formation of the vallum is a function only of youth in shells of this size is not altogether clear because one of the specimens is flat. Another is moderately curved, but its vallum is not well-formed anteriorly. In *E. chaotica*, adult lateral septa tend to be strongly oblique to the inner surface with the dip toward the back. In such septa the two original septa may be obscured, or the anterior one may appear at or near the crest of the lateral septum and the other near the base on the posterior side. This broad obliquity of the septal groove is a common feature of this species. In late-formed septa, a groove at the crest or spread along the sloping surface is not easily detected. The posterior lateral septa, to a point near the midvalve or slightly beyond, are the most likely parts for the preservation of the septal groove. The anteriormost septa seldom, if ever, show this feature.

The lateral septa commonly are fluted strongly on both sides. The fluting of the broad dipping surface or an oblique septum is strongly striated longitudinally, but on the shorter anterior surface it suggests a strong pitting. The edge of the bra-



chial valve lobes are fluted and wavy to correspond to the undulations of the septa.

The development of the median ridge in *E. chaotica* is of interest. In the posterior part of the shell it is thin and, in some cases, not clearly shown. Furthermore, in the rear third it may bear a median groove. In the anterior third or half, the ridge becomes stronger, more elevated, and substantially solid. It is probably at this point that the brachial valve is cleft to fit snugly on both sides of the median ridge. In the anterior third or less, the ridge again lessens in height and strength and may divide into two narrow threadlike ridges with a flattened space between.

Another feature of the interior is the modification of the lateral grooves. These are commonly occupied by fairly strong, rounded ridges, often fluted on both sides. These interseptal ridges originate at the distal side of the grooves in the old parts of the shell and increase in length proximally in the later-formed shell stages.

The brachial valve of this species is strongly granulose on the exterior and the granules are well separated. The hinge is provided with well-formed ears for articulation. Furthermore, at the apex appears a small, triangular, smooth area that represents the surface over which the protruding posterior lip rubbed in the movement of the brachial valve when the animal gaped (Williams', 1953, "primary shell layer").

The cardinal process is variable and is always irregular, seldom in direct line with the median ridge. The myophores usually are small, but some are laterally expanded. The lateral lobes are generally narrow and moderately convex toward the anterior in the posterior part of the shell, but they tend to straighten anteriorly. The lobes are also less oblique to the shell axis at the apical region than near the midvalve, where the shell is generally deepest. At deep parts the lobes may be at a strong angle to the axis to accommodate to the obliquity of the lateral septa. Generally the posterior edge of the lateral lobes is somewhat flattened where it rests against the sloping edge of the lateral septum, but it is thin and sharp along the anterior margin, where it is articulated at the base of the lateral septum. In many specimens the margins of both sides of the lobes are strongly waved or fluted to fit the striations of the lateral septa.

Inside the lobes the floor usually is thickened by adventitious shell with pseudopunctae. The thickening is demarcated clearly by a groove parallel to the lobe edge and a somewhat thickened line inside the lobe edge. The line is continuous along the lobe margins, and also around the margin of the groove between the lobes.

The median axis is marked medially by a ridge of variable height in different specimens that extends from the cardinal process shaft to the median cleft. At the median cleft a low ridge extends anteriorly along the inner margin of the cleft.

*Eolyttonia chaotica* is best developed in the Cathedral Mountain and Road Canyon formations, especially at USNM 702c. It occurs lower in the former formation in the eastern part of the Glass Mountains, but the specimens are not always typical of the species at this level. The best development is at the base of the Road Canyon Formation at USNM 719x, where it is abundant. The national collection contains about 100 specimens of different sizes and varying stages of preservation from excellent to poor. The silicification is not uniform and, in some, has gone so far as to alter or mar details. The species lived in clusters and also singly, with a number of species utilized as substrate.

### *Eolyttonia circularis*, new species

PLATE 143: FIGURES 1-16; PLATE 144: FIGURES 6-14;  
PLATE 145: FIGURE 5

?*Lyttonia nobilis americanus* R. E. King (not Girty),  
1931:103, pl. 32: fig. 6.

Broad, subcircular, and shallow cones, generally deepest near midvalve; attachment scar small, generally puckered; cowl variable, usually large and folded posteriorly, but seldom overhanging the hinge. Sides and anterior margins well rounded. Surface marked by concentric lines and wrinkles.

Pedicle valve interior with narrow hinge having rounded swollen, posterior lip. Cowl in some specimens sharing in attachment. Lateral septa generally strongly convex anteriorly; lateral septa grooved (latilobate to angustilobate) in young and often in adults, but many adults with more advanced solidiseptate septa. Interseptal ridges increasingly strong and wide anteriorly; interseptal slots pitted. Median ridge low and inconspicuous.

Brachial valve with short visceral region, variable



hinge and anterior cleft from one-half to one-third valve length from front margin. Median depression moderately deep; surface finely granulose. Lateral lobes narrow and curved, convex anteriorly. Hinge with narrow articulating processes. Lobes anteriorly serrate.

Brachial valve interior with deformed eccentric cardinal process; median ridge strong and moderately elevated. Loops with fairly strong adventitious thickening.

MEASUREMENTS (in mm).—

|                        | length | maximum width | hinge width | height | cowl length |
|------------------------|--------|---------------|-------------|--------|-------------|
| USNM 702un             |        |               |             |        |             |
| 150727                 | 46.0   | 52.0          | 12.0        | 28.0   | 23.0        |
| (holotype)             |        |               |             |        |             |
| USNM 702a <sup>1</sup> |        |               |             |        |             |
| 150723a                | 45.5   | 49.0          | 10.3        | 19.0?  | 16.0        |
| 150723b                | 48.0   | 49.0          | 11.9        | 14.0?  | 10.0        |
| 150723c                | 42.0   | 53.0          | 7.0         | 15.0   | 15.0        |
| 150723e                | 40.0   | 42.0          | 12.0        | 17.0   | 17.0        |
| 150723f                | 35.0   | 45.0          | 7.5         | 21.0   | 11.0        |
| USNM 702               |        |               |             |        |             |
| 150721d                | 60.0?  | 67.0          | 12.0        | 15.7   | 15.6        |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500c, 500H, 504, 591, USNM 702, 702a, 702a<sup>1</sup>, 702b, 702 (low), 702un, 703b, 703bs, 726y; Road Canyon: USNM 703a.

DIAGNOSIS.—Large, shallow, conical *Eolyttonia* with broad cowl extended posteriorly and with maximum depth at midvalve.

TYPES.—Holotype: USNM 150727; figured paratypes: 150650, 150721d, 150723e–g, 153616a–c, 153585, 154530; measured paratypes: 150721d, 150723a–c; unfigured paratypes: 150721a–c, 150721a–c 150723a–d.

COMPARISON.—The broad, open, shallow conical form of these shells is distinctive and separates them from all of the deeply conical species. *Eolyttonia circularis* is similar in appearance to *E. chaotica*, but that species has its greatest depth in the posterior part and its cowl is many-layered and ragged in appearance, whereas the cowl of *E. circularis* is quite smooth.

*Eolyttonia diabloensis* (Stehli) has similarities to *E. circularis*, but it is a strongly papillose species with a more irregular cowl.

DISCUSSION.—The cowl and hinge are the most distinctive parts of this species. The cowl is variable

in length, but it forms a flattish posterior expansion that may or may not assist in the attachment of the shell. In some specimens the attachment scar is an irregular patch in the position of the beak, but the cowl extends above it and is entirely free. In others the cowl extends posteriorly as a flap over the attachment surface, often welding the specimen tightly to its host, and often so neatly that contact of the callus and shell is not visible. The hinge is also distinctive as a narrow slit with a strong overhanging lip that is almost bulbous in some specimens.

Most pedicle valves of adult specimens have a fair number of the lateral septa angustilobate. In the posteriormost septa the groove is narrow and occupies the crest of the ridge, but in the more anterior septa the groove is distorted and spread onto the sloping or oblique face of the septum. Many specimens have the interseptal parts occupied by low, pitted interseptal ridges. These originate early and are increasingly long anteriorly.

This species is uncommon and appears to be restricted to the lower and middle parts of the Cathedral Mountain Formation, where it occurs with *Collemataria elongata*, new species.

*Eolyttonia cornucopia*, new species

PLATE 146: FIGURES 1–6

Large and variable but forming well-defined and nearly complete cones having fairly acute apex; length and width variable, usually longer than wide; cicatrix of attachment small; cowl long, almost equaling length of ventral side. Surface marked by concentric lines and wrinkles.

Pedicle valve interior with at least 15 lateral septa, posterior ones generally in angustilobate to solidiseptate stages of development. Posteroproximal parts of lateral septa most elevated, decreasing in height anteriorly; all lateral septa low anteriorly and with moderate development of interseptal ridges. Median ridge low and continuous nearly to hinge.

Brachial valve not seen.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| 150627a    | 89.0   | 61.0          | ?           | 45.0   | 45+         |
| 150627b    | 68.0   | 61.0          | ?           | 45.0   | 61.0        |
| 150627c    | 70.0   | 66.0          | ?           | 41.0   | 36.0        |
| (holotype) |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base).

LOCALITIES.—USNM 720e.

DIAGNOSIS.—Large, strongly conical *Eolyttonia* having a fairly acute apex.

TYPES.—Holotype: USNM 150627c; figured paratype: 150627b; unfigured paratype: 150627a; measured paratypes: 150627a, b.

COMPARISON.—This species was seen only at USNM 720e, and there in only one biohermal patch. Unfortunately the specimens are not well preserved and are very ragged; nevertheless, the strong and sharply pointed conical form is well shown. No brachial valves were found with the specimens or in place within the cones. Many of the cones were crusted inside and out by a brownish laminated material, now silicious, that strongly indicates encrusting algae.

### *Eolyttonia diabloensis* (Stehli)

PLATE 140: FIGURES 1–25; PLATE 162: FIGURES 11–18

*Leptodus? diabloensis* Stehli, 1954:307, pl. 18: figs. 12–14.

*Lyttonia nobilis americanus* (Girty) R. E. King, 1931:103, pl. 32: figs. 1a, b.

This is a variable species defined by its author as having “simple lateral ridges and median ridge; without dental plates (or) a true median septum; growth habit conical.” Stehli failed to designate a type specimen from the two illustrated. We, therefore, choose the specimen illustrated on his plate 18: figure 14 as lectotype (AMNH 27290/1:2). This specimen, which is only a pedicle valve, is selected rather than that shown by figures 12 and 13 because it shows important generic details that cannot be seen in the other more complete specimens.

The form of this species is important in its definition. It is said to be conical, but a wide range of forms occurs. The lectotype forms an open cone with a broad cowl moderately deflected toward the anterior. The paratype is somewhat more conical, but it has a shorter cowl that is arched more abruptly over the hinge. The prevailing form seems to be like that of the lectotype, with a broad cowl variably deflected. The species thus ranges from nearly completely flat to a fairly well-formed cone.

This broad range of form is owing to the host to which it is attached and to the nature of the attachment. Usually it is attached at the apex, but,

if the host is flat, the cowl will extend posterodorsally, rather than anterodorsally, and the shell will form a wide cone. In some the cowl remains partly attached to the host and is unable to be reflected toward the hinge. This happens in specimens that resemble the lectotype specimen of *E. americana* (Girty). Few specimens are strongly conical, but the few that are have the same strongly papillose cowl as the more open and more typical cones.

Assignment to *Eolyttonia* is based on the nature of the lateral septa and median ridge in the pedicle valve and on the character of the brachial valve. Young specimens still attached to the host have a well-marked vallum and a fairly open median ridge. They thus suggest specimens of *Poikilosakos*, but they do not have the eccentric diductor muscle characteristic of that genus. In youthful flat specimens the vallum is still discernible, but the lobes are latilobate to angustilobate. Fairly large adults have many of the lateral septa distinctly and occasionally deeply grooved (angustilobate), but the grooving is generally restricted to the posterior half or less of the lateral septa. Some have lateral septa in which the proximal part near the median trough is deeply trenched, but the depression is pinched shut at the distal end of the lateral septum (solidisepate).

The median ridge is generally low and inconspicuous, extending almost to the hinge. In the posterior of some specimens it has a depression in it or it consists of two thin parallel ridges. In others the ridge is a single moderately elevated plate. At midvalve in nearly all specimens the ridge is single and strong. Variably at the anterior, the ridge bears a groove or is divided and becomes much lower until it disappears.

The brachial valve is extremely variable in several respects. Young specimens are strongly cleft anteriorly, but this becomes filled during growth. The filling may take place at several points along the cleft, resulting in a number of holes along the anterior midline, as in the dubious genus “*Gubleria*.” The filled track of the cleft appears as a moderately deeply impressed sulcus along the midline of the valve. The exterior, like the cowl and interseptal areas of the pedicle valve, are strongly papillose. In some young shells the papillae are much elongated and could be described as small spines.

The hinge region is variable, but usually it has small articulating nubs and a small triangular area representing the range of movement between the brachial valve and the pedicle valve hinge.

Inside the brachial valve the cardinal process is variable from small to large, asymmetrical to fairly regular, and usually has four myophore surfaces. The median ridge is not well developed in the visceral region, but strong and thick anterior to it. Lateral lobes are moderately deep, but not strongly thickened with adventitious shell. The inner margins along the median cleft are strongly thickened.

#### MEASUREMENTS (in mm).—

|           | length | maximum width | hinge width | height | cowl length |
|-----------|--------|---------------|-------------|--------|-------------|
| USNM 728e |        |               |             |        |             |
| 153586f   | 29.4   | 38.0          | 6.6         | 11.0   | 9.0         |
| 153586h   | 36.0   | 42.0          | ?           | 25.0   | 24.0        |
| 153586-l  | 58.0   | 61.4          | 10.0        | 25.0?  | 12.0        |

STRATIGRAPHIC OCCURRENCE.—Lower Bone Spring Formation.

LOCALITIES.—AMNH 625, 628, 629, 631, 632, 696, USNM 725c, 728e, 728f, 728h.

TYPES.—Lectotype: AMNH 27290/1:2; figured paratypes: AMNH 27290/1:1; figured hypotypes: USNM 153586a-L, 150620a, 153648, 153649.

### *Eolyttonia fredericksi* (R. E. King)

PLATE 144: FIGURES 1-5; PLATE 147: FIGURES 1-14;

PLATE 148: FIGURES 1-6

*Parakeyserlingina fredericksi* R. E. King, 1931:102, pl. 31: figs. 7-8 (not fig. 9=?) .

*Leptodus* species Huang, 1936:489, 490, pl. 1: figs. 1, 1a.

Variable shape, generally in form of irregular cup, anterior side generally more elongated than posterior side with cowl over hinge region. Attachment area generally small, puckered about attachment surface; exterior marked by strong concentric wrinkles. Hinge narrow, with swollen posterior margin. Septal lobes numbering 15 in large specimen (latilobate to angustilobate). Posterior half of lobes generally strongly elevated, inclined forward in concave specimens and decreasing in height anteriorly. Interseptal callosity developing with third or fourth lobe on outside and progressively approaching midline in anteriorly succeeding lobes. Median ridge moderately elevated extending from near hinge to anterior margin,

usually grooved medially posteriorly and also anteriorly in many specimens.

Brachial valve exterior smooth, with narrow lobes, with long median depression and median slit decreasing in length with age. Interior with thickened lobe margins and double ridge running anteriorly along margins of median slit.

#### MEASUREMENTS (in mm).—

|           | length | maximum width | hinge width | height | cowl length |
|-----------|--------|---------------|-------------|--------|-------------|
| USNM 701c |        |               |             |        |             |
| 150670a   | 60.5   | 67.0          | 7.0         | 19.0?  | 20.4        |
| 150670b   | 61.0   | 46.7          | ?           | 36.5   | 20.0        |
| 150670c   | 40.0   | 57.2          | 10.0?       | 20.0   | 9.3         |
| USNM 701h |        |               |             |        |             |
| 150673a   | 35.6   | 43.5          | 7.0         | 17.3   | 9.0         |
| 150673b   | 35.0   | 40.6          | 8.0         | 25.5   | 16.0        |
| 150673c   | 71.0   | 35.0          | ?           | 46.5   | 28.0        |
| 150673d   | 50.0   | 54.0          | 8.0         | 38.0   | 41.6        |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2-14 of P. B. King), Lenox Hills Formation, Cibolo Formation.

LOCALITIES.—Neal Ranch: USNM 701, 701a, 701a<sup>3</sup>, 701c, 701d, 701h, 701k, 701-l, 706x, 721g; Lenox Hills: 705K, 705m, 707ja; Cibolo: 728-l.

DIAGNOSIS.—Large variable cones, the posterolateral septa generally with wide to narrow depressions in their crest (latilobate to angustilobate) and the anterolateral septa becoming low and indistinct.

TYPES.—Holotype: T10671a; figured paratypes: T10671b; figured hypotypes: USNM 150669a-c, 150670c, 150673, 153617a, 153618a, b; measured hypotypes: 150670a-c.

COMPARISON.—This species differs from *E. phialiforma*, new species, in attaining a greater size, a more enclosed cone, larger lip on the posterior side of the hinge, and less advanced lateral septa and median ridge. The lateral septa in the posterior part usually have the median groove filled up or nearly so, making the edge of the septa appear flat (solidiseptate). The median ridge in the adult does not have either the anterior or the posterior depressions in its crest.

*Eolyttonia fredericksi* is much larger and more conical than either of the Russian species assignable to this genus: *Keyserlingina darvasica* Tschernyschew, the type-species of *Paralyttonia*, and *Lyttonia mira* Fredericks, the type-species of *Eolyttonia*.

DISCUSSION.—*Eolyttonia fredericksi* is not common in the Wolfcampian, but it inhabited bioherms at USNM 701c and 701h. It is seen only sporadically at USNM 701d, but more prospecting in that area might bring to light some communities of this species. A few lyttoniids from the Lenox Hills Formation in Leonard Mountain and in the Lenox Hills are assigned to *E. fredericksi*. These specimens are not silicified, but they do show internal parts that suggest this species; the exterior conical form is like that of specimens from the Neal Ranch Formation.

King (1931:102) mentioned the strong inclination to the axis, 50°, of the first five lobes of his species. Our normal specimens do not show this inclination, as all of the lobes extend laterally at about a right angle. Specimens long and narrow from crowding, however, do show a strong inclination of the early formed lobes.

### *Eolyttonia gigantea*, new species

PLATE 148: FIGURES 7-12; PLATE 149: FIGURES 1-9;  
 PLATE 150: FIGURES 1-4; PLATE 151: FIGURES 1-6;  
 PLATE 152: FIGURES 1-4; PLATE 153: FIGURES 1-5;  
 PLATE 154: FIGURES 1-4; PLATE 155: FIGURES 1-6, 8;  
 PLATE 156: FIGURES 1-10.

Large, forming almost complete cone with wide elliptical anterior opening and narrow but rounded apex; usually longer than wide, maximum width near anterior margin. Shell thick, attachment cicatrix proportionately small for large cone. Aperture obliquely elliptical. Surface marked by strong but irregular concentric wrinkles.

Pedicle valve interior with straight but narrow hinge; lateral septa numbering about 22 in larger specimens, variable, ranging from narrow crested (anguliseptate) to wide crested (solidiseptate) and grooved latiseptate; septa not strongly elevated except in posterior part near median groove. Median ridge most elevated in apical region, becoming lower and broader anteriorly and dividing toward front, anterior to midvalve. Interseptal callosities not strongly developed.

Brachial valve with narrow axial region; lobes extending laterally from axis nearly at right angles, slightly bowed in anterior direction in posterior lobes, but extending directly laterally or sloping slightly in anterior direction in front part of shell;

lobes narrow, measuring about 2.7 mm in anterior-posterior direction. Surface with coarse granules.

Brachial valve lobes shallow, with thickened margins; marginal grooves narrow and deep and bordered inside by strongly beaded line. Cardinal process not seen.

#### MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 707a  |        |               |             |        |             |
| 150633     | 59.2   | 66.0          | 14.0?       | 41.5   | 39.0        |
| USNM 714t  |        |               |             |        |             |
| 150640a    | 50.0   | 55.0          | ?           | 43.0   | 44.0        |
| 150640b    | 110.0  | 70.0          | ?           | 51.0?  | 70.0        |
| 150640c    | 123.0  | 64.0          | ?           | 65.0?  | 78.0        |
| 150640d    | 92.0   | 90.0          | ?           | 80.0?  | 74.0        |
| (holotype) |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch and Sullivan Peak members). Cibolo Formation (Breccia Zone of Udden).

LOCALITIES.—Decie Ranch: USNM 707a, 708q, 714t, 732b; Sullivan Peak: 707, 707g, 710r; Skinner Ranch (base): 705b, 711d, 714p, 720e; Cibolo: 728-l.

DIAGNOSIS.—*Eolyttonia* forming large deep cups with fairly complete conical form but well-rounded apex with moderately large attachment surface. Lateral lobes numerous.

TYPES.—Holotype: USNM 150640d; figured paratypes: 150632a, b, 150633, 150634, 150640b, 150641a, 150642, 153615a-h, 153571, 153578, 153579a-e, 153580; measured paratypes: 150640a-c, 150633; unfigured paratypes: 150640a, c, d, 150641b-e.

COMPARISON.—This species can be distinguished from all others in the Glass Mountains and North America by its enormous size and almost completely conical form. No other *Eolyttonia* has a cowl so elongated that the shell becomes an almost complete and symmetrical cone.

In the completeness and large size of the cone the American species *E. gigantea* suggests *Pirgulia* Cooper and Muir-Wood from the Sosio Limestone of Sicily, but important differences may be seen. The Sicilian genus has completely conical shells, but they have an acutely pointed apex that may be long and tapering. The lateral septa of *Pirgulia* appear to be more advanced than those of *E. gigantea* because they are strongly elevated, ungrooved, and stout (solidiseptate).

DISCUSSION.—It is difficult to find first-rate speci-

mens of this species because they are generally not well silicified. For the shape to be studied, the specimens must be taken out of the rock by breaking, which is often disastrous. The silicification is so patchy in the Decie Ranch Member that one can find completely silicified specimens only on the rock surfaces. Most specimens are silicified in spots, making extraction by acid impossible. Despite these difficulties, the pedicle valve is fairly well known, although important details of the brachial valve remain to be determined. Fairly good silicified specimens occur in the Cibolo Formation in the Chinati Mountains.

Perhaps the most interesting features of this species are its size and fairly symmetrical conical form. It has the most nearly complete cone of any species of *Eolyttonia*, but the cone does not taper to a point; rather it is narrowly truncated. Thus the attachment surface is fairly large, about one-third the width. In one fairly large specimen (USNM 150633), it is 35 mm in a length of 68 mm. In another (USNM 150641a), it is about 18 mm in a length of 55 mm. The widest specimen with a length of 92 mm has an attachment surface estimated to be about 25-30 mm. The form of the cone is variable, depending on age, and it is complete, or nearly so, in large adults.

As might be suspected in such large shells, the nature of the lateral septa is extremely variable. Young specimens show a fairly complete vallum, but the lobes are fairly closely compressed (angustilobate). In young adults the lobes are like those of the type-species of *Eolyttonia*, fully formed septa with moderately deep grooves (angustilobate). Grooved septa occur also in fully grown specimens; some specimens have all or most of the lateral septa grooved. In addition to the grooving, most lateral septa are striated or pitted on anterior and posterior surfaces. Interseptal ridges are developed in many of the specimens. These are generally not strong but low and narrow.

An odd development appears in some specimens. A lateral lobe may develop far beyond its normal limits. In one shell the last formed lobe on one side cuts across the next one posterior to it, terminating its growth but aligning it precisely with the second lobe posterior to it. In another the distal end of a lobe near midvalve curves sharply posteriorly to occupy the side of the valve at the distal

ends of the next three lobes posterior to it. Similar aberrations are reported by Rudwick (1968:44) and Rudwick and Cowen (1968:159).

The median ridge is not strongly developed for such large shells. Generally the posterior fourth or third of the ridge is slender and delicate, but the median part is fairly strong and moderately elevated. In the anterior fourth or third the ridge is somewhat flattened and medially grooved. It is thus similar to that of other species.

The brachial valve of this species is poorly known, and the cardinal process has not been seen. One specimen preserving the axial region and part of the lateral lobes indicates considerable thickening of the inside of the lobes, but with a marked depression parallel to all margins of the lobes, between the edge of the lobe and the inner thickening that extends along the lobe axis.

This species is best known from the west side of the Glass Mountain and occurs where bioherms or brachiopod patches are developed in the Decie Ranch and Poplar Tank members. On the north side of the Hess Ranch Horst it is fairly rare. It appears in some abundance in the Skinner Ranch Formation bioherms on the north slope of Leonard Mountain, but it does not attain the large size that is reached in the Decie Ranch Member. It is also present in clusters or patches in the Chinati Mountains.

### *Eolyttonia parviconica*, new species

PLATE 160: FIGURES 3-10

Small for genus with long cowl and deeply conical form. Apical attachment small. Usually longer than wide and with concentrically wrinkled anterior. Pedicle valve with 6 septal lobes fairly widely separated. Septa variable, angustilobate to anguliseptate. Median ridge strong, posteriorly solidiseptate but anteriorly from about midvalve, angustilobate. Posterior slopes of septa fluted. Brachial valve unknown.

MEASUREMENTS (in mm).—Holotype (USNM 153626a): Length 23.0, width 18.4, height 13.0, cowl length 19.6; paratype (USNM 153626b): length 21.5, width 25.0, height 11.4, cowl length 15.4.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.



LOCALITY.—USNM 726d.

DIAGNOSIS.—Small, narrow cones with 6 lobes.

TYPES.—Holotype: USNM 153626a; figured paratype: 153626b; unfigured paratypes: 153626c–h.

COMPARISON.—This, the smallest of the conical species, can be recognized by the posterior to ventral flattening of the cone. It most resembles an unnamed conical form from the Lamar Member of the Bell Canyon Formation (Plate 191: figures 4–7) in its flattened form, but the latter has more septa and almost rectangular and wider aperture.

DISCUSSION.—These must have been solitary forms to have produced such a strongly conical shape.

### *Eolyttonia phialiforma*, new species

PLATE 180: FIGURES 16–21

Medium size for genus, subcircular in outline, formed broad shallow eccentric cup attached at posterior third or fourth; exterior with strong concentric wrinkles and growth lines. Cowl broad, generally expanded posteriorly.

Interior with narrow, straight hinge bulging medially and with 2 notches at each end. Septal ridges about 13 on each side, highest and strongest posteriorly, but diminishing in height anteriorly, there becoming very low; septal ridges broad and with low median depression (latilobate to angustilobate). Interseptal thickening at fourth or fifth ridge on outside and proceeding inward in anterior direction. Septal ridges bowed anteriorly to about midvalve, then gradually extending directly laterally. Median ridge fairly strongly elevated in posterior half, but descending anteriorly to become about same height as depressed septal ridges.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 721x  |        |               |             |        |             |
| 150666a    | 47.4?  | 56.0          | 5.0         | 21.0   | 17.0        |
| (holotype) |        |               |             |        |             |
| 150666b    | 48.0?  | 50.0?*        | 7.0         | 11.0   | 15.5        |
| 150666c    | 47.0?  | 47.0          | 9.0         | 14.0?  | 11.0        |

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (top of Gray Limestone Member of P. B. King.)

LOCALITIES.—USNM 701, 722x.

DIAGNOSIS.—*Eolyttonia* forming broad, shallow cups with thick septal ridges.

TYPES.—Holotype: USNM 150666a; figured paratype: 150666b.

COMPARISON.—This species occurs earlier than *E. fredericksi* (R. E. King), but it seems to share more advanced characters on the interior. It is generally flatter and has a less well-defined conical form and is shallower. Its hinge has a somewhat bulbous posterior lip in contrast to the small one of *E. fredericksi*. Inside the pedicle valve the lateral septa are thick, and few of them show the characteristic median depression, because it has been filled in. The median ridge is likewise thick and rounded and only rarely shows a median depression.

DISCUSSION.—In some specimens of this species the rounded ridge commonly occurring between the lateral septa in the anterior part is very well developed. It is low and rounded and has about the same height as the lateral septal ridge. Anteriorly these adventitious lateral ridges extend from the median trough to the distal end of the lobe, but posteriorly they originate farther and farther toward the lateral shell margin. The brachial valve of this species has not yet been found.

Another feature of interest is the occurrence of this species, which occupied a small patch near the top of the Gray Limestone Member of P. B. King. In this patch most of the lyttoniids are partially or completely covered by a layer of laminated lime, probably of algal origin. This is one of the few bioherms that shows definite evidence of algal deposits.

### *Eolyttonia pocillata*, new species

PLATE 158: FIGURES 1–25

Moderately large, elongated, crudely cup-shaped or bowl-shaped, anterior side elongated and posterior side forming elevated but seldom elongated cowl, sides rounded and fairly strongly curved in dorsal direction; anterior usually flattened. Surface strongly marked by fine, concentric wrinkles.

Interior with narrow hinge having moderately overhanging ledge and lateral articulating notches. Lateral septa numbering maximum of 14, strongly to moderately bowed anteriorly, posterior 4–6 being grooved (angustiseptate) and strongly to moderately elevated, those anterior to these lower and becoming indistinct near anterior margin. In-

terseptal callosity strongly developed, appearing early in shell development in first formed lobes and extending from outside inward, and strongly developed anteriorly; septa and callosities pitted or longitudinally striated; median ridge low, best developed posteriorly, poorly developed and occasionally obsolete anteriorly.

Brachial valve hinge variable but narrow, straight, with short, broadly triangular smooth area at posterior representing area in contact with pedicle valve hinge. Articulating flange small; exterior marked by prominent longitudinal depression; anterior cleft open in young forms but closed in adults; lobes narrow, measuring 2 mm or less in longitudinal direction; lobes not connected. Surface smooth.

Brachial valve interior with small eccentric cardinal process; lobes moderately deep with adventitious ridge paralleling them; median ridge low, extending full length of shell to median split.

#### MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 702b  |        |               |             |        |             |
| 150653a    | 30.3   | 28.0?         | 7.3         | 13.7   | ?           |
| 150653b    | 27.0   | 24.2          | 6.6         | 18.0   | 7.5         |
| USNM 702un |        |               |             |        |             |
| 150658a    | 46.2   | 42.6          | 8.3         | 16.8   | 5.7?        |
| 150658b    | 34.6   | 25.0          | 6.0         | 27.0   | 5.0         |
| 150658c    | 30.2   | 24.1          | 6.0?        | 14.1   | 4.0         |
| 150658d    | 27.0   | 31.6          | 6.0?        | 10.1   | 8.0?        |
| 150658e    | 29.8   | 30.0          | 6.4         | 10.1   | 3.5         |
| 150656f    | 39.7   | 34.0          | 7.3         | 10.3   | 3.2         |
| 150656g    | 34.4   | 28.2          | 7.3         | 14.2   | 5.0         |
| 150658h    | 38.8   | 48.0          | 8.5         | 16.7   | 7.8         |
| 150658i    | 19.5   | 22.0          | 4.6         | 6.9    | 7.3         |
| 150658j    | 33.7   | 35.6?         | 9.3         | 8.0    | 6.6         |
| 150654     | 41.1   | 38.2          | 6.5?        | 14.0   | 9.4         |
| USNM 702   |        |               |             |        |             |
| 150651a    | 39.7   | 43.7          | 9.6         | 18.3   | 13.0?       |
| 150651b    | 29.2   | 32.3          | 7.0?        | 10.8   | 7.9         |
| (holotype) |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Cathedral Mountain Formation.

LOCALITIES.—Bone Spring: AMNH 497, 591; Cathedral Mountain: AMNH 500F, 500K, 500L, 500N, 500X, USNM 702, 702a, 702b, 702 (low), 702un, 703b, 703bs, 708, 732u.

DIAGNOSIS.—*Eolyttonia* of medium size, with a short cowl having few lateral septa in the pedicle valve (about 10–14), generally grooved (angustilobate), and with interseptal ridges well developed.

TYPES.—Holotype: USNM 150651b; figured paratypes: 150651a, 150653b,k,o,q–s, 150654, 150658b, 150623, 150624; measured paratypes: 150651a, 150653a,b, 150658a–j, 150654; unfigured paratypes: 150651a, 150653a, c–j, m, n, p.

COMPARISON.—This species is most like *E. chaotica*, new species, but it differs in being smaller with about 14 or fewer lateral septa, in having a poorly developed cowl, and generally in having more septa in the angustilobate condition. The median ridge is poorly developed compared to that of *E. chaotica*. The brachial valve interior of the lobes is covered by thicker adventitious deposits that nearly fill the lobe except for the narrow groove just inside the lobe edge.

*Eolyttonia diabloensis* (Stehli) is similar but generally larger, with less crowded lateral septa having a much lesser development of interseptal ridges. Furthermore, the lobes of the brachial valve do not have the thickening deposits in them.

DISCUSSION.—This species is definitely conical, but the cowl generally is aborted and often somewhat thickened. The most interesting feature of the species is the development of the lateral septa, which give the appearance of close crowding because of the interseptal ridge development. The septal development is extremely variable, but generally the posterior lobes are in the angustilobate stage, which becomes modified anteriorly to low but fairly simple solidiseptate. Interseptal ridges develop at an early stage and normally are elaborately formed through the entire cone. The interseptal ridge generally is crowded against the posterior walls of the lateral septum, complicating the appearance and confusing its origin and type. Both sides of the lateral ridge are pitted or striated, and the interseptal ridge becomes pitted when formed against a pitted lateral septum.

The median ridge of *E. pocillata* is poorly developed, a feature that distinguishes this species from several others. It is best developed in the posterior half, but it is low in the anterior part of most specimens and often is obscurely divided.

The brachial valve hinge is straight and usually there is a smooth area where the shell slides against the hinge. It is also provided with articulating processes. The cardinal process is small and asymmetrical when well preserved, but this feature is seldom seen. The anterior margin of the lobes

commonly is serrated strongly to accommodate the fluting or striation of the lateral septa. The inner parts of the lobes are heavily filled with adventitious material, leaving a narrow groove inside the lobe margins and the inner thickening.

The median cleft of the brachial valve is short in adults. As the cleft is eliminated anteriorly by deposition of shell material at the proximal end, the effect on the interior is to produce a broad, carinate median ridge. This is strongly developed along the axis but less so in the hinge region.

*Eolyttonia progressa*, new species

PLATE 159: FIGURES 1-10; PLATE 160: FIGURES 11-19;  
PLATE 161: FIGURES 1-11

*Lyttonia nobilis americanus* R. E. King (not Girty), 1931:103 (part), pl. 32: fig. 7 (only).

Large, variable, generally broadly triangular in outline with rounded front margin and irregular sides; posterior narrowed and overhanging hinge in form of fairly broad cowl, attachment usually small, with callus flap behind it; generally flatly convex in lateral profile but broadly convex in cross section. Surface marked by irregular concentric wrinkles.

Pedicle valve interior with narrow hinge having strong rounded lip above it; lateral septa numbering about 18 in large adults, 8 septa in 25 mm usually fairly strongly elevated at least in posterior three-fourths; septa with fairly broad, flattened (solidiseptate) or in some cases distally grooved (angustilobate) crests. Lateral septal lobes low; interseptal callosities generally not strongly developed and usually best established by anterior third, where septa are low. Median ridge low, rounded, strongest in median region, widening, flattening or dividing at anterior as insert to brachial valve cleft.

Brachial valve generally irregular in shape, narrow visceral body bearing median depression; lobes narrow measuring about 2.4 mm in longitudinal direction, not distally united.

Brachial valve interior with quadrilobed, symmetrical cardinal process becoming greatly swollen in adults; shaft grooved; median ridge flattened and divided or grooved just anterior to cardinal process, moderately elevated anteriorly; lobes moderately deep, with beaded marginal ridge parallel to their sides; proximal ends of posterior interlobe

spaces partially filled by webs of adventitious shell; valve anteriorly cleft in anterior third.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 728   |        |               |             |        |             |
| 150749a    | 67.0+  | 72.0          | ?           | 49.7   | 33.0        |
| 150749b    | 59.6   | 79.4          | 12.0        | 15.0   | 19.0        |
| 150749c    | 54.0+  | 57.4*         | 13.0        | 21.0   | 13.0        |
| 150749d    | 41.0+  | 51.5          | 12.6        | 12.4   | 22.4        |
| USNM 716v  |        |               |             |        |             |
| 150740a    | 81.0   | 81.0          | ?           | 21.0?  | 18.0?       |
| USNM 715i  |        |               |             |        |             |
| 150739a    | 57.0   | 51.0          | 10.0        | 14.0?  | 5.0?        |
| 150739b    | 77.0   | 87.0          | ?           | 21.0?  | 23.0?       |
| USNM 714o  |        |               |             |        |             |
| 150738     | 48.0   | 68.0          | ?           | 21.0?  | 23.0?       |
| USNM 719z  |        |               |             |        |             |
| 151311a    | 67.5   | 46.0          | ?           | 30.0   | 33.7        |
| (holotype) |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (Appel Ranch Member).

LOCALITIES.—Getaway: AMNH 21, 496, 512, 519, 600, Moore 31, USNM 728, 730, 732; Appel Ranch: USNM 704, 714o, 715i, 716v, 719z, 722t, 727j.

DIAGNOSIS.—Large *Eolyttonia* with the width equal to, or greater than, the length and with strongly elevated lateral septa in the pedicle valve.

TYPES.—Holotype: USNM 151311a; figured paratypes: 150739c, 150746a, 150749a,d-i 151311b-d, 153625; measured paratypes: 150738, 150739a,b, 150740a, 150749a-d; unfigured paratypes: 150739a,b, 150749c.

COMPARISON.—This species is easily distinguished from all others of the genus by its extremely wide conical form and the strength and elevation of the lateral septa in the pedicle valve.

DISCUSSION.—The species is represented by a fair number of specimens, but they are not well preserved and many are fragmentary. It is identified in the Guadalupe Mountains as well as in the Glass Mountains. Naturally, with such a wide geographical gap between them, the specimens from the two places show some differences, but they do share in common the strongly elevated lateral septa, the number of the septa in 25 mm, and other details. The specimens from the Guadalupe are thick-shelled and robust. The Glass Mountains specimens are not as stout, but they are, nevertheless, large, strong shells.

Too few of the specimens are complete enough

to show the cowl in undamaged condition, but the Glass Mountains specimens generally have it extending over the hinge to make a cone. Growth of the cowl in a posterior direction is unusual, but some small specimens have this feature, thus producing broad open cones. The Guadalupe Mountains shells are generally cones with the cowl extending over the hinge, but apparently a larger proportion of specimens also has the cowl growing more posteriorly than posterodorsally. Consequently, some large specimens that are open cones appear in the collection.

Small specimens of this species have the lateral septa grooved latilobate to angustilobate, and the very young have a well-marked but anteriorly incomplete vallum. Many adult specimens display grooving along the crest of the lateral septa in their distal parts, the septa along the axial channel being rounded. Many septa are strongly oblique, especially in convex individuals, and the dip of the septa is toward the posterior. Specimens nearly flat or slightly concave have the septa nearly perpendicular to the valve floor.

The median ridge is fairly strongly developed, but it is not greatly elevated in any of them. It is generally low and threadlike at the posterior of many specimens, and, in others, its anterior part is grooved for some distance, but this feature is not uniform.

The brachial valves have no noteworthy differences. In both geographic regions they seem to have about the same amount of internal callus deposit. The median ridge generally is developed strongly in specimens from both areas.

The smallest specimen of this species comes from USNM 716v in the Glass Mountains. It is about 16 mm in diameter and is in the 4-lobe stage, having strongly grooved lateral septa and a straight narrow hinge. The specimen is nearly flat, having been attached on a fenestellid frond. The direction of the branches of the fenestellid have been impressed on the interior of the thin shell and have produced an oblique striation of the interior. The collection is not sufficiently rich in young specimens to trace the ontogeny of the species.

### *Eolyttonia* species

PLATES 160, 162, 191

Several species of *Eolyttonia* are represented by

specimens too poor to describe as separate species. These specimens are from a number of stratigraphic levels and are best discussed on the basis of their geological appearance.

### *Eolyttonia* from Sullivan Peak Member

Six lots are from this level; four are unsilicified and were taken from matrix by splitting the rock. The specimens are large, all are fragmentary, and none shows the complete shape. The large size suggests relationship to *E. gigantea*, but the completely conical form of that species cannot be proved, nor can any other significant details.

LOCALITIES.—USNM 708e (USNM 150791), 711d (USNM 150793), 715h (USNM 150794).

### *Eolyttonia* species 1 from Taylor Ranch Member

PLATE 160: FIGURES 1, 2

The specimens from this horizon come from several localities, but two types of facies are represented: specimens from a sponge bioherm (702d) and from a muddy bottom.

LOCALITIES.—USNM 702d, 702m (USNM 150788), 716n (USNM 151310), 716o (USNM 150796), and 716c.

Specimens from the sponge bioherm are extremely variable, some being widely triangular, but others somewhat elongate. The lateral septa, however, suggest mutual relationship because these are of fairly advanced type without grooves (solidiseptate) or with the grooves, shallow (angustilobate), and oblique or confined to the oldest shell part. Many of the lateral septa are anguliseptate, with some deeply excavated anteriorly and with sharp crests. Furthermore, in the widest specimen the lateral septa are strongly elevated, very broad, and are strongly striated in a longitudinal direction.

Brachial valves preserving the posterior half can be removed from two of the specimens to show a broad, deeply cleft cardinal process and a prominent median ridge. Both of these valves have the lateral lobe bifurcated.

The sponge bioherm is surrounded by fine-grained, brittle, somewhat siliceous limestone that weathers into nodules or cobbles. Fossils, mostly brachiopods, are enclosed partially by the nodules



and are frequently well preserved and fairly abundant. They include the large productoid *Peniculauris imitata*, which is the distinctive species of this level. Lyttoniids are rare in the nodular beds and are seldom well preserved. Several pedicle valves are in the USNM collection along with a few brachial valves completely isolated from their companion valves. The pedicle valves are normal, gently convex to slightly concave in lateral profile, but gently convex in anterior profile or cross-section. Several specimens are concave medially, but the best interior in the collection is a large pedicle valve (USNM 150788) nestled against one ear of a large *Peniculauris*. This specimen is deeply concave, and its shape is controlled by the curvature of the brachial valve of the productid. As a result, the lateral septa of this specimen are mainly in the anguliseptate stage. The hinge, however, is clearly visible and the cowl is smeared out over the ear and hinge region of its host. The lateral septa of the more normal, nearly flat pedicle valves are less elevated, less oblique, and with well-marked grooves along their crests (angustilobate) in the older parts of the shell. The lateral septa of the anterior parts are low and inconspicuous and have strongly developed interseptal ridges. Striation of the septa is not strong in any specimen.

Brachial valves are notable for the slenderness of the axial region and the lateral lobes. They are also deeply but narrowly cleft to about the mid-valve and have a coarsely, pustulose exterior.

The preservation of these two groups of lyttoniids, the one from the bioherm and the other from a muddy bottom, are so different that it is difficult to relate them. They may be the same species, but the material at hand does not permit a decision in the matter. Furthermore, it is not possible to relate the specimens from the nodules to any of the species named herein. The specimens from the bioherm are somewhat similar to *E. circularis*, but they are narrower posteriorly and not so deep.

**TYPES.**—Figured specimens: USNM 150788, 153627.

#### *Eolyttonia* from Cathedral Mountain Formation

Two lots of a lyttoniid different from the abundant specimens in the Split Tank area need special mention.

#### *Eolyttonia* species 2 from USNM 702un

PLATE 162: FIGURES 1-7

The specimens from this locality differ from *E. pocillata* in being more elongate, deeper, with a smaller cowl, and highly advanced lateral septa in the pedicle valve. The best-preserved specimen is 45 mm long and about the same width at the anterior. It is conical in form, moderately convex in lateral and anterior profiles, but with a strongly truncated apex where it attached. Its living position must have been fairly erect. The cowl is moderately long and commonly overhangs the hinge for 10 or more millimeters. Inside the pedicle valve the lateral septa are mostly anguliseptate, delicate and thin, and deeply excavated. They descend in height anteriorly, where the anteriormost two or three out of the 12 maximum are low and inconspicuous. Their posterior slope is generally striated. In the young the lateral septa are angustilobate, but high at the posterior. The interior of the brachial valve is unknown.

**TYPES.**—Figured specimens: USNM 150769a-c.

#### *Eolyttonia* species 3 from Lamar Limestone Member

PLATE 191: FIGURES 4-7

Two specimens from the Lamar Limestone indicate an undescribed species. These are completely conical pedicle valves. One specimen has two individuals adhering to each other by the long cowl, which makes a complete cone, the posterior and anterior sides being almost equal. The lateral septa are moderately elevated, about 9 in number and are slightly over 2 mm. In this respect, these specimens internally resemble *Collemataria spatulata* from the same horizon. The median ridge is low and rounded. The hinge is at the base of the cowl.

**LOCALITY.**—USNM 738b.

**TYPPS.**—Figured specimen: USNM 150774.

#### *Eolyttonia* species 4 from Capitan Limestone

One specimen from the Capitan Limestone (USNM 725-1; USNM 151317), is a strongly conical form with closely spaced septa and a long cowl. The specimen suggests the conical form from the Lamar Limestone noted above.



## Genus *Petasmaia* Cooper and Grant, 1969

[Greek *petasma* (spread out)]

*Petasmaia* Cooper and Grant, 1969:10.

Usually large, broadly expanded anteriorly, but commonly narrow posteriorly where attached to crinoid stem or to other narrow object; profile flat to gently convex; surface marked by concentric growth lines and wrinkles.

Pedicle valve interior with narrow hinge with strong posterior lip, muscle region bounded by strong, thin, slightly divergent plates; lateral septa numerous, usually latilobate to angustilobate in young, but generally thin and oblique in adult (solidiseptate to anguliseptate) median ridge low, thin, and delicate, open or split only at extreme distal end.

Brachial valve consisting of numerous lobes convex anteriorly, median axis grooved longitudinally and cleft narrowly at anterior; axial region commonly narrowly convex; surface smooth; hinge narrow and with small, deflected articulating points.

Brachial valve interior with double but bifurcated, short-shafted cardinal process with 4 myophore surfaces. Median ridge moderately well developed; lobes moderately deep.

TYPE-SPECIES.—*Petasmaia expansa* Cooper and Grant (1969:10, pl. 2: 15–18).

DIAGNOSIS.—Large expanded Lyttoniidae having strong, divergent plates bounding muscle region and well-developed complete cardinal process.

COMPARISON.—This genus at present need be compared only to *Oldhaminella* Wanner and Sieverts (1935) and to *Leptodus* Kayser (1883), which have elevated plates bounding the muscle region. *Oldhaminella*, however, is a much smaller creature and is strongly convex, a fact that led to its name—derived from convex *Oldhamina*. *Petasmaia* is generally not strongly convex, but it varies from nearly flat to moderately curved. Furthermore, *Petasmaia* has many more lateral septa and lobes than *Oldhaminella*. Another important difference is the fact that the Timor genus has two strong muscle ridges on each side of the muscle region, the inner pair running parallel to the median ridge for some distance. Wanner and Sieverts (1935) described the lateral septa as in the “*Eolyttonia*” (latilobate to solidiseptate) stage in the outer half,

but in the *Oldhamina* stage (anguliseptate) in the inner half. In the Glass Mountains genus these stages can be recognized, the “*Eolyttonia*” stage in the young and the “*Oldhamina*” stage in the adults, especially in the more convex individuals.

*Oldhaminella* is not a well-known genus because only two ventral valves were described and the brachial valve is not known. The two described specimens were attached to crinoid stems, which so irritated the stem that the crinoid deposited additional lime, some of it concealing part of the brachiopod. No such phenomenon was seen in connection with *Petasmaia*, which also has an affinity for crinoid stems.

*Petasmaia* is similar to *Leptodus*, as that genus is now conceived, in its expanded form and in the presence of lateral plates in the apical region. It differs, however, in having much stronger lateral plates, which are subparallel, and it seldom shows the musculature as the Pakistan shells do. Its lobes in the posterior are somewhat less advanced than those in *Leptodus* in the same place. The lateral lobes of *Petasmaia* are usually oblique to the inner surface and are usually strongly carinate or almost knife-edge sharp (anguliseptate). Those of *Leptodus* are blunt and usually nearly erect.

DISCUSSION.—*Petasmaia*, like other members of the Lyttoniidae, is variable in outline and profile. The variability is mainly owing to the kind of host on which it started life. Most specimens in the collection are attached to crinoid stems or other narrow objects, such as the curved posterior of the pelecypod *Leiopteria*, and to narrow brachiopods. The favorite attachment site is the crinoid stem, which affects the form of the shell. Specimens thus attached generally have narrow posterior regions and strongly narrowly convex median areas in the brachial valve. The brachiopod generally wraps a strong sheath of shell material around the crinoid stem to form an attachment tube. Convexity develops as the anterior of the shell grows away from the crinoid stem. We suppose that the *Petasmaia* lived with its posterior down and the anterior margin up when attached to a crinoid stem, but it is possible, as Grant (1963) has shown with spat of *Linoproductus*, that direction of growth is entirely an accident of the position of settling.

Although *Petasmaia* appears to have preferred narrow objects on which to grow, a healthy animal

was not deterred if it settled on a flat object. On such substrate the pedicle valve may form a veneer over the surface for as much as 25 mm. Such individuals usually are broadly rounded in outline without any posterior attenuation and the shell may range from flat to moderately convex, depending on age and the congeniality of its surroundings.

The hinge of the pedicle valve of *Petasmaia* is like that of *Collemataria* in having a strong posterior lip over the slit and lateral notches. The horizontal slit is deep and the lateral notches strong, with the anterior shelf serving to receive the articulatory processes of the brachial valve. The deep notches and overhanging lip serve as articulating joints and for holding the brachial valve in place.

The strong lateral plates diverging from the inner ends of the articulating notches of the hinge have been interpreted as dental plates or the remnants of these structures. Actually no articulating processes or teeth occur in the pedicle valve, and this interpretation is therefore doubtful. These lateral plates are herein regarded as bounding plates of the muscle area, similar to, but more elaborate than, the sheath surrounding the single muscle in *Poikilosakos* and *Pseudoleptodus*. In most specimens these plates or lateral myophragms are simple, thin, erect septa originating at the inner ends of the articulating notches and extending with slight divergence anteriorly to the second or third lateral septum. In one specimen (USNM 151343g) the plates are not erect but are curved inwardly, strongly suggesting the muscle sheath of the *Poikilosakidae*.

The lateral septa are variable in adults as well as in the young. In immature specimens a close resemblance to the vallum of *Poikilosakos* or *Pseudoleptodus* is shown by the fact that the wall is continuous and produces inlobes and outlobes, the latter usually the wider. The vallum of the young, however, is not continuous with the median loop anteriorly, as in the more primitive genera.

With advancing age and increasing size, the lateral lobes are crowded anteriorly, some of the posterior lobes in large specimens becoming angustilobate proximally, but solidiseptate to anguliseptate distally. In adults generally the lateral lobes have become anguliseptate and are sharp-edged septa lying at a low angle to the inner surface. Minor fluting of the septa at right angles to the

edge is clear in some specimens, but this development is not as strong as in later genera.

The median lobe of the smallest specimens, as well as of the largest adults, has been laterally compressed into a single ridge divided or open only at the extreme distal extremity, and this for a short distance only. The ridge extends from the horizontal hinge groove anteriorly almost to the anterior margin. Near the margin its height decreases, and in some specimens a division into two faint ridges may be seen.

The hinge region of the brachial valve seen from the exterior is characterized by two small points that are deflected in a dorsal direction and serve to articulate the valve to the lateral notches of the pedicle valve. Also present is a small, smooth triangular area having a widely obtuse angle and two small lateral angles. This area (Williams' "primary shell") represents the surface of movement of the posterior of the brachial valve in the horizontal groove against the posterior articulating lip of the pedicle valve hinge.

The cardinal process consists of twin myophores joined to a shaft, the whole consisting of two shafts and four myophore surfaces. The two shafts and twin myophores are separated by a deep groove. The whole structure lies at approximately the middle of the hinge, but it does not always terminate or lie in the path of the median ridge. This cardinal process contrasts strongly with that of the *Poikilosakidae*.

The brachial valve of *Petasmaia* is cleft anteriorly for about one-third its length. The cleft is filled proximally as the shell grows, leaving a fairly strong longitudinal sulcus behind it.

**OCCURRENCE.**—*Petasmaia* is not a common genus and has been found only in the Glass Mountains, normally in the Cathedral Mountain Formation at the level of *Institella*, with a single fragment having been found in the Road Canyon Formation. Furthermore, it has been found mostly at Split Tank and westward as far as the Old Word Ranch. It was not seen in the residues from the Wedin Member of the Cathedral Mountain Formation in which *Institella* is so common.

#### *Petasmaia expansa* Cooper and Grant

PLATE 163: FIGURES 1-8; PLATE 164: FIGURES 1-16;  
PLATE 165: FIGURES 1-23; PLATE 169: FIGURES 11-16

*Petasmaia expansa* Cooper and Grant, 1969:10, pl. 2: figs. 15–18.

Pedicle valve large, variable in shape and convexity, generally narrow posteriorly and expanding widely anteriorly, greatest width forward of midvalve; more rarely widely subcircular; usually gently concavoconvex but varying from nearly flat to moderately curved longitudinally. Exterior surface with growth lines only, but commonly with uneven surface from impinging against neighbors. Attachment commonly to narrow round objects such as crinoid stems or bryozoa, resulting in forms with narrow posterior and scalloped posterolateral margins; more rarely attached by part of posterior to flat objects, resulting in more circular form. Attachment callus or posterior flap moderately large, frequently folded completely around object of attachment and along posterolateral margins. Lateral nonseptate areas flat to moderately folded in dorsal direction on posterolateral margins, usually flat to slightly deflected in anterior half to third.

Pedicle valve interior with narrow, straight hinge slightly produced and moderately elevated; hinge margins of both valves in contact; lateral sockets deep; interarea (?) flat and triangular. Muscle field elongate, subtriangular in outline and bounded by strong, erect plates tangential to first 1–3 septal lobes and bounding median, trough. Lateral septa variable, numbering 20 in largest specimens, strongest posteriorly and decreasing in strength laterally and anteriorly. Young septa in some specimens latilobate to angustilobate, but in others solidisepate to anguliseptate; young septa nearly vertical but later ones medianly situated in old shells steeply inclined, dipping posteriorly at low angle to valve surface. Septa strongly convex anteriorly in posterior but gently convex toward anterior in anterior half. Crests of lateral septa ranging from 4 to 6 mm apart. Posterior surfaces of septa generally faintly grooved in direction of long axis of young shells but beaded in old ones; interseptal spaces generally smooth but in old shells coarsely pitted in rows adjacent to anterior side of septum. Median longitudinal septum, low, carinate, and continuous from hinge nearly to anterior margin.

Brachial valve conforming to curvature of pedicle valve; exterior finely pustulose. Hinge narrow and nearly straight with strong pointed and slightly deflected lateral articulating processes; posterolat-

eral lobes narrow but widening progressively to midvalve. Posterior body moderately convex and fairly deep, marked centrally by narrow, shallow depression extending to median cleft at anterior; median cleft variable in length depending on age. Lateral lobes strongly rounded in cross section. Median trough moderately deep; median ridge strongest at midvalve, vestigial or absent posteriorly. Cardinal process small, without buttress.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | midwidth |
|------------|--------|---------------|-------------|----------|
| USNM 702b  |        |               |             |          |
| 151341a    | 85.9   | 85.9          | 11.0        | 83.0     |
| 151341b    | 66.0   | 76.0          | 8.0         | 63.0     |
| 151341c    | 55.0   | 62.0          | 7.0         | 54.0     |
| 151341d    | 23.0   | 24.0          | 5.0         | 24.0     |
| 151341e    | 25.0   | 23.5          | 4.5         | 23.5     |
| 151341f    | 19.0   | 19.0          | 4.0         | 19.0     |
| 151341g    | 10.5   | 11.5          | 3.0         | 11.5     |
| USNM 702un |        |               |             |          |
| 151343     | 71.0   | 65.4          | 10.6        | 65.4     |
| (holotype) |        |               |             |          |
| 153601a    | 75.0   | 85.0          | 11.0        | 80.0     |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (*Institella* beds).

LOCALITIES.—AMNH 500E, 500F, 500H, 500L, 504, USNM 702, 702a, 702b, 702-low, 702un, 703b, 726u, 726x.

DIAGNOSIS.—*Petasmaia* generally with narrow posterior but broadly expanded anterior region.

TYPES.—Holotype: USNM 151343; figured paratypes: 151441a, d–g; unfigured paratypes: 151341b, c; measured paratypes: 151341a–g; figured hypotypes: 151339, 151345, 153598, 153599a, b, 153600, 153601a, b, 155128b–h, 155129a–e.

COMPARISON.—When seen from the inside, this species is readily distinguished by its lateral myophragms. When only the exterior is visible, it is generally distinguishable from *Eolyttonia* Fredericks, with which it occurs, by the narrowed posterior but expanded anterior and shallow convexity. The brachial valve also is generally deeper posteriorly than those of the other genera.

DISCUSSION.—This species is rare in the Split Tank area and just west of there. It is best developed at USNM 702un, where it occurs in its maximum size. At USNM 702b it is seldom found in living position because that deposit consists chiefly of shell debris in a thanatocoenose; nevertheless,

the best immature specimens were taken from this locality. The species is extremely rare at USNM 703b.

Bain (1971:134) illustrated and described an inverted specimen of *P. expansa* that is attached to a crinoid stem by the pedicle valve beak; the specimen provides the substrate for attachment of an individual of *Hercosia uddeni* (Böse), whose spines and much of the surface of the *P. expansa* are covered by an encrusting fistuliporid bryozoan. The pedicle valve of *P. expansa* was identified (Bain, 1971) as the brachial valve of a species of *Derbyia*, incredibly suggesting that *Derbyia* could have lived and grown to large size while the function of the articulating apparatus, including the cardinal process, was defeated by direct impingement of a crinoid stem. The upright position of the *H. uddeni* indicates that, if the crinoid was living when *P. expansa* attached to it, the orientation of *P. expansa* had the pedicle valve up and the brachial valve facing the sea floor. Such orientation would have protected the openly pinnate brachial valve from settling sediment by providing a rooflike pedicle valve. The single example, however, with its obvious ambiguities, does not prove that this was the preferred orientation of *P. expansa*.

### *Petasmaia* species 1

Fragments of a large *Petasmaia* were taken from the Road Canyon Formation at USNM 720d and 736x, showing still another link of this formation to the Leonardian. The specimens were attached to a crinoid stem in life, as usual with the genus, and the lateral septa are well preserved. Only four of the lateral lobes are preserved, and the median region is keeled. The size and shape of the species represented are problematical.

TYPES.—Described specimens: USNM 151345, 154922.

### *Loxophragmus*, new genus

[Greek *loxos* (slanting) + *phragmos* (wall)]

Small, transversely elliptical in outline and conical in profile; cowl short but strongly overhanging hinge region; attachment at apex small; surface marked by concentric lines and wrinkles.

Pedicle valve interior with straight hinge line having lateral grooves for articulating but without

projecting posterior lip. Vallum developed in young but adult shells with broad, 6–7, oblique, low, lateral septal ridges usually strongly fluted or striated and descending in elevation anteriorly; median ridge low posteriorly but strong and thick near midvalve, becoming divided anteriorly.

Brachial valve with 6–7 narrow lateral loops; shell body short; shell cleft anteriorly from one-half to two-thirds length from anterior end; cleft narrow. Exterior granular.

Brachial valve interior with small eccentric cardinal process; median ridge low; lobes moderately concave.

TYPE-SPECIES.—*Loxophragmus ellipticus*, new species.

DIAGNOSIS.—Small Lyttoniidae with strongly oblique lateral septa (terminivallate).

COMPARISON.—This genus suggests *Keyserlingina* Tschernyschew in its form and profile, but it has a strong median ridge and the lobes of the vallum modified to strongly oblique, single-crested lateral septa (solidiseptate to anguliseptate).

DISCUSSION.—This genus is unusual in producing advanced *Oldhamina*-like lateral septa (anguliseptate) in a shell with otherwise primitive characters, such as the deeply cleft brachial valve and the dual median ridge.

### *Loxophragmus ellipticus*, new species

PLATE 137: FIGURES 21–22; PLATE 152: FIGURES 5–8;  
PLATE 166: FIGURES 1–37

Small, incomplete cone; width generally greater than length; greatest width near midvalve; profile gently to moderately convex. Cicatrix of attachment small, attachment flap variable, cowl short. Surface with strong concentric wrinkles and fine lines of growth.

Pedicle valve interior with narrow hinge having lateral articulating sockets; lobes numbering 9 in fully grown adult; initial loops narrow; posterior 4 lobes generally bowed strongly in anterior direction, tilted strongly anteriorly and deeply undercut; crests of early loops usually with single crest (solidiseptate to anguliseptate), but occasionally double-crested (angustilobate) lobes strongly striated longitudinally, measuring 2.5 to 3 mm from crest to crest; anterior 2–4 lobes slightly elevated, elevation decreasing anteriorly, last lobe sometimes diffi-



cult to determine. Median ridge generally thick and moderately elevated, with single crest on posterior but anteriorly decreasing in height, flattened to grooved along crest and, when grooved, suggesting division into 2 ridges. Interseptal lateral callosities, low, developed only anteriorly in last 2-3 lobes.

Brachial valve with narrow lobes and short body; hinge straight with lateral articulating flanges; cardinal process consisting of 1 slightly eccentric lobe with 2 muscle scars; median ridge low; concave side of lobes with trough and elevated line parallel to lobe margins, which are thickened. Median cleft extending for about three-fourths valve length.

MEASUREMENTS (in mm).—

|                | length | maximum width | hinge width | height | cowl length |
|----------------|--------|---------------|-------------|--------|-------------|
| USNM 702b      |        |               |             |        |             |
| 150683a        | 24.2   | 27.0          | 5.2         | 9.6    | 5.3         |
| 150683b        | 19.6   | 22.3          | 3.7         | 7.6    | 3.3         |
| 150683c        | 20.8   | 22.4?         | 5.4         | 6.7    | 4.0         |
| 150683d        | 18.2   | 22.0          | 4.3         | 8.1    | 1.0         |
| 150683e        | 15.4   | 24.1          | 3.3         | 5.9    | 2.8         |
| 150683f        | 20.6   | 23.2          | 5.1         | 5.5    | 4.4         |
| 150683g        | 15.9   | 23.0          | 3.7         | 6.8    | 3.0         |
| 150683h        | 15.0   | 22.3?         | 5.5         | 6.2    | 4.4         |
| 150683i        | 15.0   | 19.6          | 4.2         | 6.0    | 3.6         |
| 150683j        | 16.2   | 19.6          | 3.9         | 6.8    | 5.3         |
| 150683k        | 14.0   | 18.5          | 4.0         | 5.6    | 3.0         |
| USNM 702 (low) |        |               |             |        |             |
| 150685         | 19.6   | 27.3          | ?           | 8.2    | 5.8         |
| (holotype)     |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (*Institella* Zone), and upper Cathedral Mountain.

LOCALITIES.—AMNH 500, 500D, 500L, 500N, USNM 702, 702b, 702ent, 702 (low), 702un, 703b, 703bs, 726x, 735b.

DIAGNOSIS.—Small, laterally expanded *Loxophragmus* with early lobes of the pedicle valve strongly inclined forward and anteriorly excavated.

TYPES.—Holotype: USNM 150685; figured paratypes: 150681 c, d, 150682a-c, 150683b, g, 150686a, 153611, 153612a, b, 153613, 153614a-d; measured paratypes: 150683a-k; unfigured paratypes: 150681a, b, 150683a, c-f, 150686b.

COMPARISON.—The small size and generally elliptical form separate this species from all others of the genus. The species, which resembles some forms of *Keyserlingina* Tschernyschew, has a more advanced type of median ridge and lateral septa.

Furthermore, *Keyserlingina* has a more symmetrically conical form than species of *Loxophragmus*.

DISCUSSION.—This is an anomalous species because it has primitive features in the deeply cleft brachial valve and advanced characters in the nature of the lateral septa. The conical form is unusual with only a small development of the cowl. The earlier genus, *Keyserlingina*, is more strongly conical. Relationships to *Eolyttonia* Fredericks seem clear in that the young have a fairly well-developed vallum. In later stages the shell is unusually advanced in the character of its lateral septa, which are similar to *Oldhamina* (anguliseptate) except that the septa are usually nearly prone.

This species has few septa, only up to about seven or eight. Nearly all lateral septa are broad and flat, the posterior three or four strongly oblique to the valve floor, but the more anterior ones usually are only slightly elevated. The surface of the septa are broad and flat and usually striated. The broad, flat surface represents the groove along the septal edge so characteristic of *Eolyttonia*. Usually the slight ridge forming the posterior side of the groove can be seen at the posterior base of the septum. These septal ridges, thus, are very oblique, resulting in a widening of the distance between segments of the vallum.

The median ridge is generally fairly thick, originating at the hinge where it is low but strengthening and heightening anteriorly to midvalve or beyond. Near midvalve it flattens and widens and usually is grooved to form two low ridges.

The brachial valve is unusual for the deep cleft that extends posteriorly for more than half the valve length. The loops are narrow and moderately to strongly convex toward the anterior. The surface is granular as usual in the Lyttoniidae. The hinge region bears small ears to fit into the articulating slots of the pedicle valve.

Internally the cardinal process is small and off-center. The axial region is strengthened by ridges extending from the beginning of the cleft and running parallel to the inside wall to the anterior end.

*Collemataria*, new genus

[Greek *kolla* (cement)]

*Lyttonia* (part) R. E. King, 1931:102.



Variable, usually scoop-shaped, large, with subtriangular outline, apex narrow, anterior expanding; attached at beak or apex by posteriorly growing callus and usually further cemented by broad flap over attachment and part of host; sides posteriorly somewhat narrowly folded in dorsal direction. Surface marked by concentric lines and wrinkles.

Pedicle valve interior usually with numerous lateral septa, generally oblique and ungrooved (solidiseptate) in adults, but may be grooved in young (angustilobate); median ridge moderately well developed, reaching to hinge; margin of cowl forming upper lip of hinge.

Brachial valve with slightly deflected ears but without articulating processes; hinge usually narrow; valve anteriorly cleft, slit healed from posterior toward anterior or at numerous points between; median depression strong.

Brachial valve interior with variable cardinal process having divided shaft and 4 myophore surfaces. Median ridge low and thick.

TYPE-SPECIES.—*Collemataria elongata*, new species.

DIAGNOSIS.—Usually large Lyttoniidae with progressive lateral septa, posterior callus flap for attachment, and hinge forming margin of cowl.

COMPARISON.—*Collemataria* in its outline and profile is most like *Leptodus* Kayser, from which it differs in not having signs of any musculature or bounding plates in the apical region of the pedicle valve. Although the attachment area of *Leptodus* is like that of *Collemataria*, the hinge of the former is revealed as a narrow slit with a posterior lip and, thus, is unlike that of *Collemataria* in which the anterior margin of the cowl serves as the lip of the hinge. We were unable to find any clear distinction between the lateral septa of the two genera, thus making it necessary to have complete specimens for identification.

*Collemataria* differs from *Eolyttonia* Fredericks in form and outline, but especially in the relationship of the hinge to the cowl. In *Collemataria* the cowl is outside the hinge, which appears as a slit with overhanging lip; the lip, in some species, is thick and often bulbous. The lateral septa of *Collemataria* are somewhat more advanced (solidiseptate) than those of *Eolyttonia*, which often has the

majority of the septa deeply grooved medially (angustilobate).

*Petasmaia* Cooper and Grant and *Coscinophora* Cooper and Stehli are the only other large American Lyttoniidae, but they are so unlike *Collemataria* that close comparison is unnecessary. The former is usually narrow at the hinge and has well-marked plates bounding the muscles. *Coscinophora* is unique in being fragmentivallate, all septa modified to rows of beads and the brachial valve a solid plate with perforations matching the beads.

### *Collemataria americana* (Girty)

PLATE 157: FIGURES 3-6; PLATE 181: FIGURE 12

*Leptodus americanus* Girty, 1909:212, pl. 25: figs. 1-3a.

This species has been identified widely throughout the Permian areas of this country from many different stratigraphic levels. Obviously a variety of species, probably also genera, have been thus misidentified. One of Girty's specimens has also been assigned to the genus *Rigbyella*, after Wanner and Sieverts (1935) had indicated that it did not belong to *Leptodus*. The true relationships of this species largely depend on determining the locality from which Girty's specimens came. This is now almost impossible, but it seems certain that they came from the Sierra Diablo, although the exact level is not known definitely. According to Girty (1909:512) the specimens come from USGS 3764, a locality mentioned in Von Streeruwitz's report (1893:170), which is said to be "along the cliffs on the east side of the Sierra Diablo, about 8 miles north of Hazel Mine." This would locate the section approximately opposite the north end of the Baylor Mountains and about 2.5 miles south of Victorio Peak. This also puts the locality into close proximity with those collected by F. G. Stehli and ourselves, near the mouth of Victorio Canyon.

Not only does the geographic location suggest Stehli's material, but also the preservation and color of Girty's types are like those of Stehli's specimens. Girty's specimens are well silicified, stout but brittle, the color a yellowish brown like some of the Stehli material preserved at the American Museum of Natural History and some specimens at the United States National Museum. It is possible, therefore, to suggest that the level from which

"*Leptodus*" *americanus* was taken is the lower part of the Bone Spring Limestone.

Although all of the evidence points to the location and horizon of Stehli, to prove that this species belongs to either of Stehli's described species from the Sierra Diablo is more difficult. Stehli (1954:307, 308) described *Leptodus? diabloensis* and *Leptodus? marshalli* and distinguished them mostly on the type of attachment and the general form of the shell. The former is definitely conical and was attached without a callus flap, whereas the latter had a narrow posterior attachment with strong callus. *Collemataria americana* appears to be most like *Leptodus? marshalli* in having an expanded callus flap and elevated lateral septa with an obscure groove along the crest of several of them (angustilobate to solidiseptate). *Collemataria marshalli*, however, is differently shaped and not strongly granulose.

*Leptodus americanus* is herein assigned to *Collemataria* because of its posterior flap, cowl, and the angustilobate nature of the lateral septa. Several of the lateral septa have a fairly well-marked groove along the crest, as is characteristic of at least the early formed lateral septa of *Collemataria*. The median ridge is fairly strong and, in the paratype (USNM 118513a), is divided at the anterior. A fragmentary brachial valve (USNM 118513b) has a small eccentric cardinal process, a strong median ridge with median depression, and an anterior cleft. It is not possible to say whether or not these interior characters, based on one specimen, are a mark of the species rather than the details of the specimen.

Girty did not designate a type for his species. We, therefore, select the largest and most nearly complete specimen, USNM 118513, as lectotype. The other two specimens, an incomplete pedicle valve

(USNM 118513a) and an incomplete brachial valve (USNM 118513b), are paratypes.

Types.—Lectotype: USNM 118513; paratypes: 118513a, b; figured hypotypes: 153582.

### *Collemataria batilliformis*, new species

PLATE 167: FIGURES 1-40; PLATE 168: FIGURES 1-45;  
PLATE 169: FIGURES 1-10

Small, usually elongate, length commonly about twice width; sides converging anteriorly to form narrow groove or, rarely, a tube; sides more usually strongly folded in dorsal direction to form deep trough; attachment cicatrix usually small but commonly with large callus flap; cowl usually short, often not formed; surface marked by irregular concentric wrinkles or fairly smooth.

Pedicle valve interior with 9 lateral septa, posterior 6 fairly well raised, single (solidiseptate) or double crested (angustilobate) posterior septa usually sloping posteriorly and undercut on anterior side; septal ridges fluted, strongly in some specimens, moderately in others; median ridge narrow and moderately raised posteriorly, variable, widening, flattening or noticeably dividing anteriorly at variable distance from visceral cavity, becoming row of beads or dots (moniliseptate) at anterior in some. Interseptal callosities developed in old or large adults.

Brachial valve generally with deep cleft; lateral lobes irregular, occasionally branched or intergrown; shell body short, moderately deep. Exterior marked by fairly strongly scattered pustules.

Brachial valve interior with small, eccentric cardinal process commonly with swollen myophore; median ridge low; lobe margins scalloped, strongly curved toward pedicle valve to form fairly deep channels; ridges parallel to lobe margins strong and inter-ridge areas thickened and granulose.

## MEASUREMENTS (in mm).—

|                    | length | maximum<br>width | width at<br>front margin | hinge<br>width | height | cowl<br>length |
|--------------------|--------|------------------|--------------------------|----------------|--------|----------------|
| USNM 721j          |        |                  |                          |                |        |                |
| 150815a            | 27.0   | 18.2             | 10.5                     | 4.0?           | 7.0    | 2.8            |
| 150815b            | 22.6   | 13.5             | 4.3                      | ?              | 9.4    | 3.3            |
| 150815c            | 14.5   | 7.8              | 3.9                      | ?              | 8.5    | 4.6            |
| 150815d            | 28.0   | 13.5             | 6.0                      | 4.3?           | 9.5    | 10.0?          |
| 150815e            | 18.0   | 15.0             | 6.0                      | ?              | 10.0?  | 5.7            |
| 150815f            | 25.0   | 13.2             | 6.4                      | ?              | 13.4   | 3.7            |
| 150815g            | 27.0   | 11.8             | 6.7                      | ?              | 13.0   | 13.0?          |
| 150815h            | 15.8   | 9.5              | 3.4                      | ?              | 6.0    | 3.2            |
| 150815i            | 25.6?  | 16.0             | 5.6                      | 4.8            | 6.4    | 8.0            |
| 150815j            | 26.7   | 17.0             | 4.0                      | ?              | 9.0?   | 5.0            |
| 150815k            | 30.0   | 16.3             | 13.6                     | 4.7            | 8.5    | 3.5            |
| 150815l            | 11.6   | 12.0             | 5.6                      | ?              | 10.3   | 5.0            |
| 150815m            | 20.7   | 13.0             | 7.0                      | 4.0            | 9.3    | 9.3            |
| USNM 726d          |        |                  |                          |                |        |                |
| 153603s (holotype) | 27.4   | 18.7             | 5.0                      | ?              | 12.0   | 11.0           |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 721j, 721z, 722v, 724c, 726d, 732j.

DIAGNOSIS.—Small, elongate *Collemataria* with narrowed anterior ends producing a narrow trough, or, in some specimens, a tube.

TYPES.—Holotype: USNM 153603s; figured paratypes: 150815c, l, 153602a–j, 153603b, c, e–i, l–q, t–z; measured paratypes: 150815a–l; unfigured paratypes: 150815a, b, d–k, 153603a, d, j, k, r.

COMPARISON.—The small size, elongate form, and tubular anterior end make this species unique for the genus and not closely comparable to any other species.

DISCUSSION.—This unusual little species is abundant about 25 feet below the top of the Road Canyon Formation. There it occurs in a layer about one foot thick, which is a coquina of fusulinid shells and other fossil debris. The specimens all show evidence of transportation in partly broken brachiopod tests and well-rounded fragments of fusulinids. *Collemataria batilliformis* is scattered throughout the debris. Most specimens appear as single valves rather than as clusters, suggesting that masses were broken or that the specimens lived singly or in small groups but were ripped off their moorings. A fair number of this species occur broken in the rock and probably were not broken in the solution process.

The exterior form of this species is extremely variable, ranging from shallow open specimens to

ones that are almost complete tubes. The latter have strongly curved sides, and some have the sides united at the anterior to form a tube. The tubular anterior is generally an adult feature, but some small specimens not half the length of the normal adult occur with the anterior formed into a complete tube. These may be old but stunted forms, “geromorphs” in the jargon. On the other hand, many of the largest specimens have not produced a tubular anterior. They are, however, usually narrowed into a restricted channel at the front, but they remain open on the dorsal side. It is possible that the formation of a tube is a fortuitous occurrence induced by crowding. The feature does not seem universal enough or sufficiently regular to be regarded as more than evanescent.

As usual with this type of shell, the attachment and cowl are variable. The cowl may grow almost wholly posteriorly, leaving the hinge completely revealed, or else it may grow forward sufficiently to hide the hinge, producing a broad flap over the object of attachment. Many specimens attach to round objects, while others spread out on flat surfaces to produce obvious aberrancies.

Inside the pedicle valve the usual variations in the form and development of the lateral septa may be observed. Young specimens have a well-developed vallum except at the anterior. Growth squeezes the ridges forming the lobes together in an anterior-posterior direction to become angustilobate and finally to produce narrowly rounded septal ridges (solidiseptate). Grooved ridges occur in

specimens of any size, but the advanced, sharp, strongly oblique ridges (anguliseptate), deeply undercut, are generally found in the adults and in shells of considerable depth.

The median ridge is low, but conspicuous and solid, thinnest near the beak but stout a short distance anterior to it. The ridge is commonly grooved (angustilobate) for two-thirds of its length, and the grooved part is exposed between the long cleft in the brachial valve. In at least one specimen the median ridge is moniliseptate.

In an environment as rough as that in which *C. batilliformis* must have lived or to which it was transported, it is only natural that the brachial valves were detached and often destroyed. This valve is, therefore, rare compared to the more resistant pedicle valve. The brachial valve, like the pedicle valve, also shows infinite variation. Usually it is slender and delicate, cleft medially for one-half to two-thirds of its length from the anterior. This naturally makes the valve weaker in its resistance to transportation. The lateral lobation is also variable, some lobes are branched, and others coalesce with adjacent ones. In one the lateral axial branches have joined to produce an almost solid plate except for a short central slit and a few slits and holes on the sides (Plate 167: figures 3, 4). The interior, unlike the outside, presents no novel features.

### *Collemataria elongata*, new species

PLATE 139: FIGURES 11, 17-20;

PLATE 170: FIGURES 1-16; PLATE 171: FIGURES 1-18;

PLATE 172: FIGURES 1-16; PLATE 173: FIGURES 1-40;

PLATE 181: FIGURES 12-15; PLATE 183: FIGURES 22-23;

PLATE 191: FIGURES 10

*Lyttonia nobilis americanus* R. E. King (not Girty), 1931:103, pl. 32: figs. 2, 3, 9.

Pedicle valve large, variable, scoop-shaped, generally narrow and elongate, expanding gradually anteriorly to attain maximum width anterior to midvalve; pedicle valve forming shallow elliptical dish, flat to strongly convex in lateral profile but gently convex in anterior profile, sides abruptly reflected in dorsal direction. Exterior surface usually irregular without ornament other than concentric lines and wrinkles of growth. Attachment callus (posterior flap) generally small, but occasionally large over substrate, occasionally folded part way

along sides and rarely forming cowl reminiscent of *Eolyttonia*. Nonseptate lateral areas forming narrow marginal band.

Pedicle valve interior with narrow but variable hinge; lateral sockets nearly obsolete; brachial valve held in place by socket formed by posterior fold of pedicle valve; interarea obsolete (?). Articulating nubs small, not present or not seen in all specimens. Muscle field and bounding ridges obsolete or obscure. Lateral septa numerous 8 in 25 mm, having maximum of 27 extending close to margin, highest in posterior and median regions, decreasing in height anteriorly and barely visible at margin of many specimens. Septal crests variable; in some specimens younger crests grooved (angustilobate) but at midvalve generally narrowly rounded to sharply carinate (solidiseptate to anguliseptate). Granulose interseptal ridges appearing between septa laterally in older parts of shell, gradually lengthening toward midline in younger and wider parts, septal crests 3 to 3.5 mm. apart. Old septa pitted, striated, or beaded on both sides in old specimens; interseptal spaces pitted variably in strength depending on age. Median ridge continuous from apical region nearly to margin, generally low, usually narrowly rounded.

Brachial valve exterior finely papillose; apical callosity triangular, small. Body usually slightly convex. Hinge irregular, variable, seldom straight. Articulating processes rudimentary or obsolete. Lateral lobes narrow, strongly convex in section, slightly arcuate toward the posterior not in contact laterally.

Brachial valve interior with long, low, rounded median ridge extending anteriorly from cardinal process to front margin. Median trough about 4 mm wide. Lobes deep, with minute row of beads running parallel to walls and around curve, there lobe meeting median trough. Cardinal process small, buttressed by median ridge in many specimens, and with myophores divergent.

### MEASUREMENTS (in mm).—

|           | length | maximum width | hinge width | midwidth | height |
|-----------|--------|---------------|-------------|----------|--------|
| USNM 706e |        |               |             |          |        |
| 150821a   | 104.3  | 41.5          | 9.0?        | 32.5     | 18.8   |
| 150821b   | 82.3   | 45.0?         | 14.0?       | 44.5     | 9.7    |
| 150821c   | 79.8   | 38.4          | 15.0?       | 32.0     | 8.2    |
| 150821d   | 64.4   | 54.4          | 15.7        | 33.6     | 15.7   |
| 150821e   | 67.4   | 40.0          | 11.2?       | 33.0     | 15.0   |

|            | length | maximum<br>width | hinge<br>width | midwidth | height |
|------------|--------|------------------|----------------|----------|--------|
| 150821f    | 55.7   | 29.7             | 11.0           | 29.0     | 11.7   |
| 150821g    | 44.0   | 32.4             | 10.9           | 27.4     | 17.9   |
| 150821h    | 37.5   | 30.0             | 7.4            | 26.0     | 9.6    |
| 150821i    | 42.8   | 29.0             | 6.8            | 25.7     | 10.5   |
| 150821j    | 37.4   | 22.4             | 5.2            | 20.0     | 8.0    |
| 150821k    | 23.7   | 20.0             | 5.2            | 14.8     | 8.3    |
| 150821-l   | 18.4   | 20.5             | 4.3            | 19.0     | 5.8    |
| 150821m    | 19.8   | 17.8             | 4.0            | 15.6     | 6.4    |
| 150821n    | 18.8   | 13.8             | 3.9            | 12.0     | 5.8    |
| 150821o    | 18.4   | 13.8             | 3.4            | 11.0     | 4.0    |
| 150821p    | 11.0   | 9.3              | 2.8            | 8.3      | 3.7    |
| 150821r    | 3.3    | 4.7              | 1.3            | 4.4      | 1.3    |
| 150821s    | 70.0   | 30.0             | 5.0?           | 27.0     | 12.0   |
| (holotype) |        |                  |                |          |        |
| 150821t    | 14.6   | 9.9              | 2.6            | 9.6      | 2.8    |
| 150820a    | 7.8    | 11.1             | 3.0            | 10.0     | 2.0?   |
| 150820b    | 8.8    | 8.5              | 2.7            | 8.5      | 4.0?   |

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, and Appel Ranch members and lenses between the last two).

LOCALITY.—China Tank: USNM 706c, 706z, 726r, 733q; Willis Ranch: 706, 706e, 718d, 723t, 734u, 732s; lenses: 706b, 732c; Appel Ranch: 704, 710, 714o, 715i, 716v.

DIAGNOSIS.—Large *Collemataria*, elongate and expanding moderately anteriorly but with strongly elevated lateral septa in the pedicle valve.

TYPES.—Holotype: USNM 1050821s; figured paratypes: 150817a, b, 150819a, b, 150820c-n, 150821a, e, 153628b, d-w, 153629, 153630, 153631a, b, 153632a-g, 153633, 153634a-i, 153638a-d, and 153566; measured paratypes: 150821a-p, r, t, 150820a, b; unfigured paratypes: 150820a, b, 150821 b-d, f-r, 153628a, c.

COMPARISON.—*Collemataria elongata* is comparable to *C. gregaria*, new species, but important differences may be noted, some of which require a number of specimens for determination. The outline of *C. elongata* is usually more elongated than that of the Cathedral Mountain species and is usually less expanded anteriorly. This is an overall picture of the material. Individual specimens of either species may be short and expanded, depending on conditions, but, in general, the Word species is less expanded anteriorly than *C. gregaria*. Another distinction between the two is the height of the lateral septa in the pedicle valve, those of *C. elongata* having the greater height. The median ridge is also unlike, that of *C. gregaria* being

low and inconspicuous compared to that of *C. elongata*.

Two differences may be observed in the brachial valves of these two species. The lateral lobes of some specimens of *C. gregaria* are joined at their distal ends, a feature that has not been observed in the Word species. The blister-like expansions along the axial region of the exterior of *C. elongata* have not been observed in the Cathedral Mountain species.

A difference was noted in the development of the young of these two similar species. Young specimens of *C. gregaria* less than 25 mm long seldom show a smooth hinge line because in most of them the margin of the cowl forms the hinge line. In *C. elongata*, on the other hand, many of the young have the hinge smooth, as in *Eolyttonia*, but others of the same size have it and the cowl corresponding, as in the adult condition.

DISCUSSION.—*Collemataria elongata* undoubtedly lived in small clusters, probably smaller than those of *C. gregaria*. Evidence is extant that, among the larger number of specimens making up the collection of *C. elongata*, few large clusters have been found. The few usually show a large individual with a few smaller ones clustered on it. This may not represent the true conditions because *C. elongata* normally is found in a death assemblage with no specimens in place except the small or tiny attaching forms. *Collemataria gregaria*, on the other hand, is found in larger masses and in blocks in which the only visible specimens are this species, as at USNM 702a<sup>1</sup>. *Collemataria elongata* commonly occurs in accumulations of dead shells; specimens are usually attached to small productids or other small holdfasts that are not particularly stable.

The type of attachment alluded to above is common with *C. elongata*. The spat are commonly found attached to shells of all sizes and frequently to small shells. The ultimate form of *Collemataria* may depend on the holdfast. Spat that settles inside a dead productid shell may develop a deeply concave interior at the beginning that may affect the lateral septa, producing high and oblique plates (anguliseptate) in the young. A shell attaching to a flat pelecypod may develop a flat form with well-formed vallum. A shell that attaches tangentially to a curved surface may develop a free anterior margin early in its life.



Development of a cowl over the hinge may occur in this Word species if the spat settles in a deep hollow requiring the shell to expand anteriorly.

The lateral septa are variable in this species, but generally they are well elevated in the adult, highest in the posterior one-half or two-thirds and lowest at the anterior. In a few adults some of the septa are grooved (latilobate to angustilobate), but this is unusual. They are commonly sharp-crested (solidiseptate to anguliseptate) and range from strongly oblique, with the slope in a posterior direction, to erect and less commonly oblique, with the slope anterior and the anterior face up. These variations are generally due to changes in curvature, the more concave specimens have the septa oblique and sloping posteriorly, but the few specimens that are arched and convex dorsally have the lateral septa sloping in the opposite direction. Normally grooved septa are generally in the posterior. Oblique septa are frequently grooved, but the groove is spread along the sloping face. In young specimens and fairly large flat ones, grooved septa appear to be the rule and the grooves may be so wide that a vallum, incomplete anteriorly, is formed.

Irregularities in the lateral septa are common especially at the anterior, where all semblance to regularity may cease. Specimens subjected to distortion in growth frequently have skewed septa that may point anterolaterally or anteriorly, or they may be curved or bent proximally; distally branched lateral septa also appear in parts of the shell, and no reason is apparent for the irregularity.

Anteriorly most of the septa are pitted or striated. Interseptal ridges are developed in most adults. These appear on the distal sides of the interseptal spaces as short ridges in the posterior and lengthened inward as the shell grows. The interseptal ridges when normally developed are usually lower than the lateral septa, but they may approach them in strength. In one large shell the interseptal ridges have the appearance of the normal septal ridge, an oblique plate undercut anteriorly. This is exceptional, however, and the usual development is more toward the anterior. Some large specimens develop no interseptal ridges.

The median ridge of *C. elongata* generally is large and strongly elevated, continuous from posterior to anterior margins. Posteriorly it is usually

lower than medially or anteriorly. In some specimens the ridge is continuous for part of its length, but anteriorly it becomes broken into a string of beads (moniliseptate). In at least one it appears as a string of elongate beads for the entire length. Where it appears as beads the anterior cleft of the brachial valve is welded between the beads to produce a median row of holes—the feature used to distinguish the “genus” *Gubleria* by Termier and Termier (1960).

The brachial valve presents one exceptional feature, but otherwise it is similar to that of other species in this genus. The exterior, when well preserved, is finely papillose as usual, and the median region is marked by a long depression that indicates the elimination of the median cleft with growth. The unusual exterior character is the presence of large blisters of shell that are revealed when broken. They show the presence of more than one layer. The blisters range in size from two or three mm to ones extending for half the valve length. Indications are that the blisters were broken before the shell was entombed in the rock, because recesses in them are commonly filled with sediment and, in a few of them, attaching forms such as young *Collemataria* are cemented across the layers of the broken blister onto the layers below. This fact, together with the occurrence of sediment in a slightly cracked blister, indicates that they were hollow. What induced them is not known. They were probably not hollow in the living animal, but perhaps they were filled with liquid produced by the mantle of the brachiopod. The blisters may have been generated because of irritation to, or under, the mantle.

DEVELOPMENT.—A good series of young valves was obtained from USNM 706e, which permits a fair idea of the development of *C. elongata*. The smallest specimen has a diameter of 3 mm (USNM 153632c). It has no lateral lobes but a strong fold at the anteromedian part of the shell. The hinge appears as a straight line with lateral notches. Three specimens with a length of about 4–6 mm (USNM 150821r, 153632g, 153632e) are more advanced, having the broad median fold and one lateral lobe that defines two lobes of the brachial valve. The inlobe is not strongly developed and a vallum is not formed, the median ridge suggesting a fold rather than a ridgelike plate and not com-

posed of two septa uniting with inlobes and outlobes, as in the Poikilosakidae. Another specimen, 8 mm wide (USNM 153632a), has essentially the same structure, but the anterior sloping face of the fold and the interseptal part of the inlobe are strongly granulose. Furthermore, this specimen has a well-marked cowl. From this stage on, considerable variation exists in the formation of the cowl, in the development of the lateral septa, and in the formation of the median ridge.

A specimen, 9 mm long and 8 mm wide, has two inlobes, a fairly high median ridge that is papillose from about midvalve to the margin, and the cowl joined with the hinge, as in adults. Some specimens of comparable development have not formed a cowl but have the straight line of the hinge slightly elevated and laterally notched, as in the primitive lyttoniids.

The third inlobe appears in specimens having a length of 10 to 11 mm (USNM 150821p). Again considerable variation may be seen, but the inlobes are fairly wide and the median ridge is flattened or grooved from about midvalve anteriorly. In one, the cowl and hinge coincide, but, in another, the hinge is in the primitive condition. At 14 to 16 mm (USNM 150821) the growing shell attains five inlobes and the median ridge has a mature appearance, being slender for most of its length and anteriorly grooved for a short distance. At about 20 mm (USNM 150821o) a sixth inlobe is added and the shell has essentially mature character. It must be emphasized that, at this size and before, a large amount of variation exists in all features. One specimen of 14 mm length with four inlobes, the last somewhat poorly developed, has some lateral septa that are oblique and slope to the posterior, and also it has interseptal ridges. To be sure, the lateral septa are also grooved (angustilobate), but they are undercut anteriorly. Nevertheless, this little specimen exhibits well-advanced characters.

The smallest brachial valve in the collection is 6.5 mm (USNM 153632b) long and is in the two-lobe stage. The lateral lobes are direct, and the exterior is finely pustulose. The anterior slit extends dorsally for about one-third valve length. The lobes are shallow and not strongly rimmed, and the median ridge is not yet formed. The cardinal process is a small rounded mass not distinguishable into any recognizable features.

A specimen with three lobes measures 7.5 mm (USNM 154923a) and shows some advanced characters. Although the cardinal process is not well-developed, the margins of the lobes are thickened and a median ridge has formed. Its median cleft is about one-third the valve length. A specimen with four lobes is 9.5 mm long (USNM 154923b) and has a cardinal process with low shaft, the lobes are marginally thickened, the median ridge is broad and low, but the median cleft is equal in length to about half the valve length. Thus, at about 10 mm the brachial valve has attained essentially adult characters.

### *Collemataria gregaria*, new species

PLATE 133: FIGURE 7; PLATE 174: FIGURES 1-15;  
PLATE 175: FIGURES 1-12; PLATE 176: FIGURES 1-14;  
PLATE 177: FIGURES 1-4

*Lyttonia nobilis americanus* R. E. King (not Girty), 1931:103, pl. 31: figs. 10a, b, pl. 32: figs. 5, 6, 8.

Pedicle valve large, variable in outline and convexity, forming crude triangle, maximum width well anterior to midvalve. Usually gently concavo-convex with convexity low, some valves nearly flat, some moderately convex but rare specimens moderately to strongly concave. Exterior with growth lines and concentric wrinkles. Valve in cross section moderately deep, with upturned lateral margins except at front. Attachment surface varying from nearly entire valve to small apical cicatrix; attachment callus (posterior flap) usually not greatly thickened and with moderate expansion; exceptional specimens with small cowl developed under unusual conditions.

Pedicle valve interior with variable hinge and with brachial valve inserted in deep pit. Lateral sockets rarely preserved. Interarea obsolete. Lateral septa numerous, numbering 24 in largest specimen, variable, not strongly elevated and descending in height anteriorly, last 4 or 5 very low and often obscure and irregular. Septal crests usually well rounded (solidiseptate). Development of interseptal ridges variable, usually located in anterior half. Septa grooved (angustilobate) and beaded (moniliseptate) in anterior half; interseptal ridges commonly pitted or grooved. Median ridge appearing at apex, low and narrow posteriorly, becoming wider and more elevated anteriorly but never very

strong. Anterior part of median septum beaded in some old individuals.

Brachial valve exterior finely papillose; apical flattened area not well preserved; hinge line irregular and usually narrow and articulating processes remnantal or lacking. Lateral lobes, narrow, nearly straight posteriorly but becoming gently arcuate anteriorly; lobes commonly fused at distal ends in old parts of large specimens.

Brachial valve interior with long, low median ridge, narrowly rounded to slightly grooved on crest and extending from cardinal process shaft to anterior margin. Median trough shallow, about 5 mm wide, lobes moderately deep, with thin ridge parallel to elevated edges and running along floor. Cardinal process small, tetralobed, and well buttressed. Spaces between lobes filled in posteriorly to form solid plate at posterior of large specimens.

#### MEASUREMENTS (in mm).—

|                        | length | maximum width | hinge width | midwidth | height |
|------------------------|--------|---------------|-------------|----------|--------|
| USNM 702a <sup>1</sup> |        |               |             |          |        |
| 150802a                | 85.0   | 80.0          | 10.0        | 65.0     | 15.0?  |
| 150802b                | 92.0   | 53.0          | 13.8        | 47.7     | 18.7?  |
| 150802c                | 72.0   | 56.0          | 11.4        | 53.0     | 17.0?  |
| 150802d                | 71.0   | 54.6          | 12.5        | 44.7     | 16.6   |
| 150802e                | 76.6   | 65.0          | 9.5         | 51.0     | 12.0?  |
| 150802f                | 52.0   | 36.0          | 10.0        | 33.6     | 18.2   |
| (holotype)             |        |               |             |          |        |
| 150802g                | 37.4   | 26.9          | 6.2         | 26.9     | 10.0?  |
| 150802h                | 26.7   | 24.4          | 4.0         | 23.0     | 5.3    |
| 150802i                | 10.0   | 9.5           | 2.5         | 8.5      | 1.9    |

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—AMNH 500, 504, USNM 702, 702a, 702a<sup>1</sup>, 702b, ?702ent, 702-low, 702un, 703a<sup>1</sup>, 703b, 711q, 726u, 726y, 732u.

DIAGNOSIS.—Large scoop-shaped *Collemataria*, fairly widely expanded anteriorly and with lateral lobes of brachial valve frequently joined distally.

TYPES.—Holotype: USNM 150802f; figured paratypes: 150800a, h, 150801a, b, 150802a–c, j–l, 150806a, d, e, 153573a–d, 153574a, b, 153575, 153576, 153577a, b, 153644; measured paratypes: 150802a–e, g–i; unfigured paratypes: 150800b–g, 150802d–i, 150806b, c.

COMPARISON.—This species is best compared to *C. elongata*, new species, to which it has considerable resemblance. The Cathedral Mountain species attains a greater size and wider anterior spread than the Word species, but these details are seen

only in the fully grown adults, which are rare. Another distinction is in the lesser number of lateral septa on the interior of the pedicle valve in the Cathedral Mountain species. The young of *C. gregaria* generally are more anteriorly expanded than the young of *C. elongata*. The brachial valves of the larger specimens of *C. gregaria* have an unusual feature in the joining of some of the distal ends of the lateral lobes in the adult, a feature not seen in *C. elongata*.

These details of comparison may seem nebulous when applied to a collection of a few specimens, but they are real in the large collections from the Glass Mountains.

DISCUSSION.—As mentioned above, *C. gregaria* appears to have lived in larger aggregates than the Word species, or else the clusters were not so effectively and completely broken up as they were in the Word. Some large clusters of *C. gregaria* survived the etching process, but it is probable that even larger ones might be obtained if some method could be found to prevent collapse of the clusters with the removal of the supporting limestone. This is not true of the Word occurrence because the specimens are not in their original position of growth.

All of the remarks pertaining to the interior of the pedicle valve of *C. elongata* are applicable to that of *C. gregaria*. The lateral septa usually are fairly advanced (solidiseptate) in showing no grooving or very little grooving of the lateral septa except at the posterior or oldest part of the shell. Variations of the lateral septa and branching are also noted. The anterior of the shell is commonly a place of scrambled or much disordered lateral septa. Specimens in which the shell is bowed toward the brachial valve and thus have a concave pedicle valve have the lateral septa oblique and, with their inclined surface extending anteriorly, thus exposing the opposite side of the lateral septum from normal specimens.

The median septum in *C. gregaria* is not strongly developed, usually less so than in *C. elongata*. It also shows variations like that of the Word species. In some specimens it is not direct, but it is twisted or curved to the side. It is also, but rarely, beaded anteriorly, in which case the axis is opposed by a series of holes in the axis of the brachial valve.

Interseptal spaces commonly are pitted deeply or

striated, resulting in serration of the margin of the lateral loops of the brachial valve. Interseptal ridges usually are not strongly developed and appear chiefly in the anterior part of the shell.

The brachial valve, when symmetrically developed, is triangular in outline, tapering gradually and symmetrically toward the hinge. The median axis is marked by a moderately deep and narrow depression that meets the cleft near midvalve or anterior to that point. In many specimens anterior to midvalve, a row of holes, usually elliptical in outline, follows the axis and partially closes the cleft. This is the feature on which Termier and Termier (1960) based the genus *Gubleria*.

Inside the brachial valve of *C. gregaria* the cardinal process is moderately large, generally well formed and with a well-defined shaft. The median ridge is low, moderately thick, and continuous from the shaft of the cardinal process to the cleft. The spaces between the lobes in the posterior part are filled partly by webs of shell material to widen and strengthen the posterior axis. The lobes are unthickened internally in most specimens. Perhaps the most unusual feature of the brachial valve is the joining of the lateral lobes distally near the midvalve where they are widest. This appears to be a specific character for this species.

Very young specimens of *C. gregaria* are rare in the collection. The smallest specimen is imperfect, but it was about 6 mm in diameter. The hinge is not preserved, but a low, thin median ridge is present. The specimen has one inlobe on each side, indicating a brachial valve of two lateral lobes. The next largest specimen is about 7.5 mm long and slightly wider. It has a grooved median septum and one inlobe, which is granulose. A third, still larger specimen with a diameter of 9 mm has the hinge visible, a broad, grooved median ridge and two inlobes, indicating a brachial valve that has three lateral lobes. The interior is granulose and the inlobes are fairly wide. A specimen of 11 mm diameter is essentially the same as the preceding, with the same number of lobes and a strongly granulose interior. A specimen with length of 11.5 mm has three inlobes and a brachial valve of four lateral lobes. The 4-inlobe stage of the pedicle valve is reached at 14 to 15 mm. Interseptal ridges are developed early, at least at the 2-inlobe stage of the pedicle valve.

### *Collemataria irregularis*, new species

PLATE 129: FIGURES 22-28; PLATE 133: FIGURES 4-6, 8-11;  
PLATE 178: FIGURES 1-16

Moderately large when undistorted, usually elongate oval, variably conical, cowl short, sides strongly developed to form deep scoop; longitudinally moderately convex in lateral profile. Posterior flap for attachment; surface marked by concentric lines and wrinkles; attachment area usually small.

Pedicle valve interior with narrow and straight hinge having moderately swollen posterior lip; hinge edge and cowl merging in few specimens; lateral septa numbering 14 to 15 in large adults, 8 occupying length of 25 mm; posteriormost half of septa strongest elevated; anterior half low and anteriorly obscure. Older septa commonly grooved (angustilobate) and those of young specimens usually grooved widely (latilobate) and forming valium; some lateral septa strongly inclined and sharp-edged (anguliseptate) but showing evidence of longitudinal groove. Median ridge posteriorly indistinct, medially moderately strong and anteriorly flattened or grooved and less distinct. Interseptal ridges early formed; lateral septa and interseptal ridges in median and anterior half commonly striated to pitted.

Brachial valve externally granulose, with anterior cleft reaching posteriorly for one-fourth valve length; lateral lobes moderately oblique to horizontal, joined distally at widest part in old shells; median groove narrow and shallow; surface granulose.

Brachial valve interior with small triangular articulatory wings set off by oblique ridges; cardinal process small, with short shaft; median ridge moderately strong, medially grooved. Lateral lobes moderately thickened and with thickened and bevelled posterior margins.

#### MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | length |
|------------|--------|---------------|-------------|--------|--------|
| USNM 714w  |        |               |             |        |        |
| 150752a    | 52.0   | 35.0          | ?           | 16.0   | 12.0   |
| 150752b    | 46.0   | 32.0          | ?           | 15.0   | 21.0   |
| 150752c    | 36.0   | 34.0          | 5.0?        | 11.0   | 10.0   |
| 150752d    | 34.0   | 33.0          | 7.0?        | 16.0   | 6.0    |
| 150752e    | 34.0   | 19.0          | ?           | 11.0   | 12.0   |
| USNM 721u  |        |               |             |        |        |
| 153635a    | 51.2   | 37.3          | 8.0         | 14.0   | 11.5   |
| (holotype) |        |               |             |        |        |



STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member at base).

LOCALITIES.—Wedin: USNM 700-1, 714w, 717e, 723v; Cathedral Mountain: 703b, 721u, 723u.

DIAGNOSIS.—Deep, oval to triangular shells, with slightly developed cowl.

TYPES.—Holotype USNM 153635a; figured paratypes: 150752a, b, e-g, 153635b-f, 153636, 153643, 153645, 153657a-d; measured paratypes: 150752a-e; unfigured paratypes: 150752c, d, 153635a.

COMPARISON.—Two species are available for comparison with *C. irregularis*. It differs from *Eolyttonia pocillata*, new species, which occurs at the same stratigraphic level, in being generally larger in the adult form, more elongate oval to subtriangular in outline, and in having a less well-developed cowl. The adult of this species suggests *Collemataria gregaria*, new species, in the lack of development of the cowl of some specimens. Generally it is less triangular and smaller than that species.

DISCUSSION.—This, not a common species, has been found mostly in the Wedin Member of the Cathedral Mountain Formation, where it is usually found attached to *Institella*. The latter is not the only host form, however, because the species attached to *Neospirifer*, to a variety of bryozoans, to *Enteleles*, and to its own brethren. The variety of hosts and the irregular nature of the surface of *Institella* make the early form of attached *C. irregularis* unpredictable. The collection does not include many adults because it is possible that the unstable attachment of *Institella*, which apparently was often ripped from its moorings, made life equally precarious for *C. irregularis*. Many of the young failed to reach maturity, which was only attained by specimens moored to substantial hosts.

The region of the cowl of this species is variable, some specimens having it extended posteriorly rather than over the hinge. These types are not common; occasionally the cowl is moderately well developed and the hinge is visible beneath it. The lateral septa are variable. In the young they are mostly in the form of a moderately compressed but incomplete vallum. Young adults of six or eight inlobes generally have the lateral septa deeply grooved (angustilobate). In a few specimens, however, the lateral septa are so oblique that the groove is flattened and spread over the septal surface. A

few specimens have lateral septa as in *Oldhamina* (anguliseptate). Interseptal ridges appear early in the life of this species and are best developed in the anterior half, where they generally extend from the distal extremity of the interseptal grooves to the median trough. The median ridge is only moderately well developed and is not a conspicuous feature of the interior.

The brachial valve in the young is cleft medially to about midvalve. The cleft becomes proportionately less with growth and is gradually eliminated in the usual manner. The cardinal process is small and inconspicuous with little or no shaft. The median ridge is moderately strong, and some thickening takes place in the lateral lobes.

The holotype affords some interesting details connected with crowded living. At its anterior the specimen grew against a fenestellid bryozoan. This caused the anterior to be diverted from its normal growth into a more dorsal direction. The result was the diverting of the median trough to the left and a skewing to the left of the median cleft and, presumably, the median ridge underneath. The valve then grew back to its normal position, and the anteriormost lateral lobes on the right side became abnormally long. This sort of "injury" or distortion is fairly common in lyttoniids, but an example with both valves preserved is not commonly found.

### *Collemataria marshalli* (Stehli)

PLATE 133: FIGURES 1-3; PLATE 179: FIGURES 1-21

*Leptodus? marshalli* Stehli, 1954:308, pl. 19: figs. 1-3.

Stehli distinguished this species from *Eolyttonia diabloensis* (Stehli) on the character of its attachment, claiming that *Collemataria marshalli* (Stehli) lived suspended above the bottom. We believe that the two species are different, but not for the same reason, because a fairly large suite of specimens shows no uniformity or preference in the form of attachment. This seems to be as haphazard as that of *E. diabloensis*. The smaller species is *E. diabloensis*, which does not produce any specimens attaining the size of *C. marshalli*. Furthermore, the lateral septa of the latter species are stronger and more distant than those of *E. diabloensis*, which has seven or eight in 20 mm, whereas *C. marshalli* has only five or six in the same distance.



The lateral septa of *C. marshalli* are thicker and higher than those of the other species, and more of them are grooved (angustilobate). They thus appear to be in a less advanced state of development than those of *E. diabloensis*. Other differences are seen in the smooth exterior and in the larger cardinal process of *C. marshalli*, the broader axial region, and broader lateral lobes.

*Collemataria marshalli* does not seem to have favored attachment to crinoid stems as Stehli avers, to judge from the collection of this species in the National Museum of Natural History. Some specimens were attached thusly and formed a tubular posterior with the attachment callus wrapped around the crinoid stem. Some attached to cylindrical bryozoans in a similar manner. But the majority of specimens attached to a variety of hosts having widely different form. Stehli mentions attachment to platycerid gastropods. Other hosts are: *Isogramma*, *Kozlowskia*, *Eolyttonia*, flat massive bryozoa, *Teguliferina*, corals, and small *Derbyia*.

In many specimens it is not possible to say what host had supported the shell because the attachment lamellae are thin and puckered as though they had attached over an irregular surface or on one that was not completely consolidated. Later the material playing host had been washed out from between the layers. We have the impression that *C. marshalli*, by necessity, settled on any surface close by when the urge to settle came on the larva.

Development of the cowl is as variable in this species as in most others of this genus. In many it is folded posteriorly and ventrally, and thus it may grow over the posterior margin and actually attach to its surface. Specimens situated differently at the beginning may have the cowl deflected anteroventrally, in which case the shell tends to become conical. The cowl in *C. marshalli*, however, is seldom sufficiently developed to produce a well-formed cone.

Young and adult specimens have grooved lateral septa (latilobate to angustilobate). Some grooves occupy the full length of the septum, but in others the groove is pinched off distally or dies out by obliquity of the septum in the same direction. In one fully grown adult of more than 60 mm length, all of the lateral septa are grooved, and the more anterior septa are widely grooved. On the other

hand, in another specimen, more convex than usual, the lateral septa are not grooved, but the position of the considerably widened groove can be seen on the oblique ridges. Interseptal ridges and interseptal pitting or striation are not strongly developed in this species.

The median ridge is inconspicuous for such a large shell. In most specimens it is threadlike in the posterior, but, in the posteromedian region, it may be grooved by an extremely narrow slit. Near midvalve the ridge is generally solid and moderately strong, but anterior to midvalve it widens somewhat and again is grooved or divided.

Few good specimens of the brachial valve have been found, but these indicate a wide visceral and axial region and a narrow hinge. Articulating processes generally are badly worn. Internally the median ridge is low but strong and extends in attenuated form to the cardinal process. The lobes are moderately convex and moderately deep with little development of adventitious shell. Growth webs between the lobes, which tend to widen the axial part, are strong and are exhibited at the posterior in most of the specimens. The cardinal process is moderately large, very irregular and with four thin myophores.

MEASUREMENTS (in mm).—Hypotype (USNM 150767a): length 66.7, maximum width 59.0, hinge width 11.0, height 16.0.

STRATIGRAPHIC OCCURRENCE.—Lower Bone Spring Formation, Skinner Ranch Formation.

LOCALITIES.—Bone Spring: AMNH 625, USNM 725c, 728e; Skinner Ranch: USNM 720e.

TYPES.—Lectotype: AMNH 27291/1:2; figured paratype: AMNH 27291/1:1, 27291/1:3; figured hypotypes: USNM 150764, 150766a, b, 150767a–e, g–j; measured hypotype: 150767a; unfigured hypotype: 150767f.

DISCUSSION.—Stehli failed to designate a type for this species. We, therefore, select the specimen illustrated on Plate 19: figure 2 (AMNH 27291/1:2) as lectotype. This seems best to typify the more abundant material from the same locality in the National Museum of Natural History.

### *Collemataria platys*, new species

PLATE 180: FIGURES 1–15

Moderately large, flat to gently concave and ir-

regular; attachment surface moderately large to nearly entire ventral surface; cowl broad, spreading posteriorly, seldom overhanging hinge; surface with strong concentric wrinkles.

Pedicle valve interior with narrow hinge having thin but conspicuous posterior lip; median ridge moderately strong, grooved or ungrooved and usually divided anteriorly; lateral septa strongly and widely grooved (latilobate to angustilobate) in young, retaining grooved surfaces posteriorly in adults; interseptal ridges strong, occupying most of lateral grooves in adults; interseptal areas strongly pitted.

Brachial valve finely papillose and with narrow, short visceral region. Anterior cleft wide in young, usually not reaching midvalve.

Brachial valve interior with strong oblique ridges setting off articulating wings at hinge; cardinal process with short, cleft shaft; myophore surface moderately broad; median ridge low, broad and stout; lateral lobe edges strongly serrated; lobes slightly thickened by adventitious shell; elimination of lobes moderately developed posteriorly.

#### MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 705a  |        |               |             |        |             |
| 150734a    | 49.0   | 50.0          | 7.0         | 14.0   | 7.0+        |
| (holotype) |        |               |             |        |             |
| 150734b    | 43.0   | 47.0+         | 7.0         | 3.5?   | 10.0        |
| 150734c    | 48.0   | 44.0+         | 7.0         | 7.0?   | 9.0+        |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation.

LOCALITIES.—USNM 705a, 715v, 722-1.

DIAGNOSIS.—*Collemataria* with nearly flat to gently concave valves and with most of lateral septa grooved (latilobate to angustilobate) at all ages.

TYPES.—Holotype: USNM 150734a; figured paratypes: 150734b-h; measured paratypes: 150734b, c.

COMPARISON.—This species suggests *Eolyttonia diabloensis* (Stehli) or *Collemataria americana* (Girty), but it differs in its generally flatter form, more strongly papillose or granulose surface, larger size, less strongly elevated lateral lobes in the posterior. This species is not likely to be confused with any other in the Glass Mountains.

DISCUSSION.—Although the collection includes a fair number of specimens, they are not well preserved. Most of the fossils at USNM 705a have

suffered from rolling about on the sea bottom and from compression after lithification of the sediment. This species occurs in the interbiohermal shell debris and, consequently, has suffered from current damage. Nevertheless, sufficient material is at hand to give a good idea of the species.

This is a variable species and, like others of its ilk, varies in shape according to the host. A fair number of specimens attached to fairly flat shells, such as a huge *Pinna*-like pelecypod, and, therefore, they produced nearly flat shells. Specimens free to grow and develop a normal shape produced shells of low convexity. This can, therefore, be regarded as a characteristic of the species.

Another characteristic of this species is the primitive nature of the lateral septa. In the young these have a well-defined vallum and widely open median ridge strongly suggesting the *Poikilosakidae*, but the vallum is not continuous anteriorly, although it is continuous laterally. In adult shells nearly all of the lateral septa show the result of compression, but all retain a well-marked groove. This is true also of old specimens, which have a fairly well-defined groove, although the anterior septa may be oblique or ill defined. Strongly pitted interseptal areas are the rule, and, in the older shells, an interseptal ridge is well developed from near the hinge to the anterior margin.

The median ridge in young shells is primitive because it divides far posteriorly and continues as two slightly diverging ridges to the anterior margin. In adults and old shells the ridge is fairly strong and is divided posteriorly and anteriorly in some individuals.

The brachial valve presents no features of unusual character and is not strongly thickened internally.

#### *Collemataria spatulata*, new species

PLATE 154: FIGURE 5; PLATE 181: FIGURES 1-11

Long and narrow, generally spatulate in form, expanding gently anteriorly; posterolateral regions strongly folded and high, descending anteriorly. Sides slightly divergent. Attachment surface moderately large, commonly flattened, shell of many specimens at right angles to cicatrix. Cowl small, usually growing posteriorly. Surface marked by concentric lines and wrinkles.

Pedicle valve interior with narrow hinge, usually independent of cowl; lateral septa numerous, nearly straight, usually not grooved (solidiseptate), generally low and fairly uniform in height, septa in posterior half, however, somewhat stronger than in anterior half. Interseptal ridges well developed, usually pitted especially in anterior half. Lateral septa measuring 11 in 25 mm and numbering about 16 in long specimens. Median ridge low and thin.

Brachial valve with narrow median axis and small triangular smooth areas at apex; median depression shallow; lobes measuring 1.4 mm in anterior-posterior direction.

Brachial valve interior with small bilobed cardinal process, long double median ridge and shallow lobes marked by beaded ridge parallel to margins.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 738b  |        |               |             |        |             |
| 150757a    | 35.0   | 21.8          | 7.0         | 10.5   | 12.0        |
| 150757b    | 28.0   | 31.0          | 6.0         | 6.0    | ?           |
| (holotype) |        |               |             |        |             |
| 150757c    | 42.0   | 25.0          | 6.0         | 8.8    | 7.0         |
| AMNH 430   |        |               |             |        |             |
| 150762     | 20.6   | 18.0          | 4.4         | 7.0    | 3.5         |
| USNM 725c  |        |               |             |        |             |
| 152628     | 63.8   | 30.5          | 6.0         | 9.0    | 8.9         |

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Lamar and McCombs members), Capitan Formation.

LOCALITIES.—Lamar: AMNH L-2, L-3, 38, 40, 401, 430, USNM 725e, 720i, 728p, 738, 738b; McCombs: AMNH 409; Capitan: USNM 737a.

DIAGNOSIS.—Small elongate and spatulate *Collemataria* with narrow lateral lobes.

TYPES.—Holotype: USNM 150757b; figured paratypes: 150757a, c, 152628, 153570; measured paratypes: 150757a, c, 150762, 152628.

COMPARISON.—This species is readily distinguished from all others of *Collemataria* by its elongate form, nearly parallel sides, fairly uniform, narrow, and numerous lateral lobes.

DISCUSSION.—The species is uncommon and difficult to obtain in good condition. The result is that the full range of variation and distinction from "*Leptodus*" *guadalupensis* Girty is uncertain (see "Discussion" in that species below). The form of its cowl and manner of attachment are fairly distinctive.

The form of attachment consists of a fairly broad surface that is commonly at a large angle to the main body of the shell, as much as 90°. The brachial valve also shares in this angular relation and may have a strong angular bend in it near the posterior. The attachment varies from a simple posterior flap to an elaborate flap of several layers at several levels.

Young specimens of 8 to 10 mm length are usually flat or nearly so and adhere by their entire surface. They have a well-marked vallum, incomplete at the anterior, but with wide inlobes. The median ridge is solid to about midvalve, where it is divided by a narrow groove. Generally adult specimens have few grooved lateral septa, but some have them, and, in others, the grooves are shallow and spread over the oblique surface of the septum. Most of the lateral lobes in most of the specimens are fairly low, thick, and broadly rounded on their crests. The lateral septa in a large specimen are remarkably uniform in height, those of the anterior half, although slightly lower, are nevertheless fairly uniform. This is a distinction from most other species of the genus.

The brachial valve presents few unusual features. The lateral lobes are narrow and thick-rimmed. Webs of callus appear in the interspaces on each side of the median trough for a considerable distance. The cardinal process is broad and has a wide depression in the shaft.

### *Collemataria* from Road Canyon Formation

The specimens from this level may be discussed on a locality basis because all of the localities have what appear to be different species.

AMNH 503 (=USNM 703).—This locality is represented best by two specimens, a pedicle and dorsal valve, both fairly well preserved. The pedicle valve (USNM 151228) has a diameter of about 43 mm, is crudely circular, and has the maximum width at about midvalve. It is moderately deep medially, probably deeper than it appears, as a slight crushing of the specimen is evident. The cowl is folded back, but the hinge is not visible. The lateral septa number 10, are fairly strongly convex anteriorly, and are angustilobate. The posterior six septa are strongest and are moderately elevated, but the anterior four are low, and the last

is barely visible. The posterior side of the grooved septa is minutely wavy. The median ridge is low, strong, and flattened medially except at the anterior fourth, where it is grooved.

The brachial valve (USNM 151228b) has fairly strongly curved lateral lobes that are convex toward the anterior. The lobes have a longitudinal distance of 2.4 mm, and the interspaces are about 1 mm in the same direction. The lobes are serrated on the anterior side and are slightly oblique to the median plane, dipping anteriorly. The cardinal process is broad, flattened but indistinct, and the median ridge is low. The lateral lobes are occupied by a median ridge separated from the margins by a narrow trough that leaves little room on the interior.

USNM 703c.—A few scraps from this locality are similar to the above except for one elongate specimen (USNM 150771). The specimens are mostly young ones.

USNM 707e.—Lyttoniidae from this locality are rare. This is, perhaps, a reflection of the type of bottom indicated by the black, muddy limestone. The few specimens indicate a fairly small species with short, wide shell, about 36 mm long and the same distance wide. The posterior flap is folded back, spreading over the host. The lateral septa are grooved or oblique and the crests are about 4 mm apart. The median ridge is strong and anteriorly grooved. The lateral lobes of the brachial valve have a longitudinal dimension of about 3 mm, but other details are not visible.

One specimen (USNM 150772) is instructive as to manner of growth. It is attached to branching round bryozoans, and the posterior flap has engulfed three of the branches. In its anterior growth the front has butted medially against another branch of the bryozoan, split at this place. Part of the shell has grown dorsad and formed a sheath around the bryozoan. After completing the closure around the stem, the anterior had started to heal the breach when the animal died.

USNM 710u.—Lyttoniids are rare at this locality, and two species are indicated by four specimens. A single specimen (USNM 150792a), 29 mm long and probably 25 mm wide, has deeply and widely grooved lateral septa (latilobate to angustilobate) and cleft median ridge. The hinge is visible, and

the posterior flap extends posteriorly, but it is small. The specimen is obviously a young one.

The other three specimens (USNM 150792b–d) are incomplete, but they suggest a small, deeply concave form about 25 mm long, 19 mm wide, and 14 mm deep. The lateral septa are anguliseptate proximally but strongly grooved angustilobate along the lateral margins. The cowl is strong with part extended posteriorly and part in a dorsad direction. These are compact, thick shells, suggesting a stunted growth.

USNM 720d.—A few specimens of a broadly conical species were taken in lenses just above limestone of the Road Canyon Formation at this place. The specimens are broad, shallow cones with an elaborate and extensive posterior flap over the attachment host. The true length of the septate portion is not known; the specimen (USNM 150798) with the largest posterior flap has a septate portion of 20 mm, but the cowl extends posteriorly for the same length and is more than twice as wide. The lateral septa in this specimen are low and simple, with the crests about 3 mm apart. The second large specimen has the lateral septa deeply and widely grooved (angustilobate). The septate part is 27 mm anterior to the hinge. The median ridge is low and inconspicuous. The lateral lobes of the brachial valve are moderately convex toward the anterior and are serrated on the anterior side. They measure 2.5 mm in the longitudinal direction of the shell axis. The cardinal process is small, and the inside of the lobes are slightly thickened.

These specimens suggest *Collemataria platys*, new species, rather than *Eolyttonia circularis*, new species, because of their generally flattened form. The extent of the posterior flap and low lateral septa do not conform to either of the other species.

USNM 721j.—*Collemataria* of uncertain character occurs with *Collemataria batilliformis*, new species, and is rare. Only two good specimens (USNM 150799a, b) have been found, but many fragments may have derived from this species. The two good specimens may be the same, the more delicate one being younger. This delicate specimen is thin-shelled and about 35 mm in length and width. It is fairly deep, about 15 mm, the posterior flap is small and extends posteriorly, but it partly engulfs the hinge, which is unusually wide, 10 mm. The sides are fairly strongly incurved and extend as an



elevation to the front margin. The lateral septa are anguliseptate, but they are slender, delicate, and deeply undercut, numbering 12 and measuring about 3 mm from crest to crest. The anterior two are very indistinct. The median ridge is fairly elevated and slender. The second good specimen was larger, but it is too imperfect to measure; it has the same wide hinge. The lateral septa are thicker, stronger, more elevated than those of the other specimens, and their true number cannot be determined because of breakage at the front. In spite of all the differences, the crests of the lateral septa of both specimens are 3 mm apart.

Fragments of immature specimens and young specimens, all pedicle valves, also appear in the collection. These have some grooved septa, as might be expected in the young, but it is difficult to link them with assurance to the two specimens described above.

Fragments of brachial valves having a size sufficient to link them to the two large specimens described above have a flattened cardinal process with cleft shaft. The lateral lobes are 2.5 mm in the longitudinal dimension of the shell, and internally they are strongly thickened by axial deposits. Similar specimens occur at USNM 702c, 703a, 706f, 712q, 716x, 716xa, 721z, 722e, 723w, 724c, 724j.

### Genus *Leptodus* Kayser, 1883

#### "*Leptodus*" *guadalupensis* Girty

*Leptodus guadalupensis* Girty, 1909:213, pl. 4: figs. 6, 6a, 6b.

The type specimen of this species is a poorly preserved impression of the pedicle valve interior and its partially preserved cowl. The apical region is flattened, but it is not clear whether this condition is owing to erosion or if it represents the cicatrix of attachment. It may be both, and, if so, it indicates a specimen that lived fairly erect. One side shows the actual pseudopunctate shell, indicating a fairly high and smooth lateral margin, but it cannot be clearly distinguished whether the margin extended into a long cowl or not. A band of concentrated growth marks at the very posterior suggests not, but, in the absence of a complete shell, it is not possible to be sure. The specimen measures (in mm): length 44, width 35.5.

The septate impression is so poorly preserved that a positive count of the lateral septa is not possible. Taken from a cast of this specimen, 12 septa can be counted on the left side, but three or four more must have existed opposite the cicatrix, now weathered away, making a total of 15 or perhaps 16 for the species. The cast also indicates a strong development of interseptal ridges, which tend to subordinate the lateral septa and make the count difficult. The spaces between the septa and interseptal ridges are pitted, and the posterior slopes of the lateral septa are striated. The median ridge is low and indistinct.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation.

LOCALITY.—USGS 2926 (green).

TYPES.—Holotype: USNM 118515.

DISCUSSION.—The stratigraphic level of this species is stated to be in the middle of the Capitan Limestone (Girty 1909:215). Other specimens found with it are said to be even more poorly preserved. It is thus almost impossible to characterize the species. *Collemataria spatulata*, new species, has some features that are similar, but the general form is different; that species is more elongate, more spatulate, and not expanded anteriorly. Furthermore, the lateral septa of Girty's species are more distant from each other than those of *C. spatulata*. Add to these facts the probability that the two species are widely separated stratigraphically, and it seems unlikely that they are the same. Girty's species must await clarification, therefore, on the basis of additional material in better quality from the type-locality.

### Genus *Rigbyella* Stehli, 1956

*Rigbyella* Stehli, 1956:310.

*Paralyttonia* (part) Wanner and Sieverts, 1935:209, 210.

Small, attached posteriorly but anterior free and making strong angle to attached part; cowl short when present; surface without ornament but with broad gentle folds corresponding to interior troughs between ridges.

Pedicle valve with strong, thick median ridge; lateral septa usually 1 or 2 on each side of median ridge and directed anteriorly or anterolaterally; lateral wall next to outermost groove forming several lobes. Hinge narrow, deeply inset. Muscle scars not clearly defined.



Brachial valve with 2 branched lateral lobes directed anterolaterally, outermost lobe with several rounded projections along outer margin. Interior not known.

TYPE-SPECIES.—*Paralyttonia girtyi* Wanner and Sieverts (1935:210).

COMPARISON.—This genus is similar to *Paralyttonia* Wanner and Sieverts (1935:207) for which it was mistaken. It differs from that genus in having a different growth form and a different septal arrangement. *Rigbyella* is attached only at the beak end, and its anterior grows at about right angles to the attachment surface. *Paralyttonia*, on the other hand, is attached by its entire surface.

DISCUSSION.—*Rigbyella* is a rare genus in the Permian of West Texas and New Mexico. It has not yet been found in the residues from the Glass Mountains. The interior lobation of the shell suggests relationship to the Poikilosakidae, rather than to the Lyttoniidae, but the muscle area of all the pedicle valves fails to reveal the unpaired muscle characteristic of the former group. Until more is known of this genus, it will have to be regarded as an aberrant lyttoniid with atavistic features suggestive of the Poikilosakidae.

The only known species of this genus is a small shell attached by most of the posterior end. The attachment may be made on flat or rounded surfaces. In any case, some callus developed around the attachment area to assist in making the hold on the host as secure as possible. The fact that many loose specimens have a hole between the hinge and the median ridge, approximating the surface of the muscle area, indicates that attachment in the beak area was thin. It was, however, thickened peripherally.

The anterior cuplike part of the shell extends at about right angles from the attachment surface and is thus erect. Such attachment habit is like that of other lyttoniids that occur in the Lamar Limestone Member with *Rigbyella*. A cowl does seem to be a common feature of this genus, and it was seen in one specimen, arching over the hinge as is usual in lyttoniids.

Based on the position of one specimen attached to *Stenosisma*, Stehli postulated that *Rigbyella* probably lived with the brachial valve horizontal. Stehli (1956:311) believed that *Stenosisma* lived with the pedicle valve down, a reasonable assumption

for free-living *Stenosisma*. If it remained attached by the pedicle, however, it may have lived with the brachial valve down, and the little *Rigbyella* occupied the sheltered underside. Furthermore, no evidence was presented that the *Stenosisma* was alive when the *Rigbyella* attached. It is likely that the *Rigbyella* on the *Stenosisma* survived because it had found firm substrate in a sheltered spot, where it could thrive regardless of its position.

The hinge of this genus is like that of other lyttoniids, a narrow slit with callus shell above it worn into a flat surface, usually triangular, by the vertical movements of the brachial valve. The brachial valve fits into this snugly. Well-preserved hinges reveal small notches on each side to receive articular nubs of the brachial valve. One specimen (USNM 147719) shows a callus development in the muscle region, but it was not possible to resolve this into definite scars. Stehli's largest specimen (AMNH 27933:1) shows the median ridge extending posteriorly as a myophragm. On each side of it are two elongate scars, which may be adductor scars because of their close proximity to the myophragm.

The septal ridges of the pedicle valve are of considerable interest because they are so different from those of any other genus. In the first place they are directed anteriorly or anterolaterally. Furthermore, although most of the specimens have a symmetrical development of the interior, this is not always true. The median ridge is the strongest and the longest and extends from the muscle region almost to the anterior margin. On each side of this median ridge appears another ridge of about the same strength but directed anterolaterally. Additional but shorter ridges may be intercalated inside the primary three or outside them. One specimen has a ridge intercalated between the median ridge and the next primary one on the right side, but, on the opposite side, the intercalated rib appears between the outer margin and the outside primary ridge. The presence of the intercalated ridges makes the lobation of the brachial valve complicated and unsymmetrical.

Of considerable interest is the lobation of the outer channel between the outside ridge and the side of the shell. In specimen USNM 147719 this is marked by a posterior depression that is followed

by three others set off by small folds of the shell. These lateral depressions produce small lobes or protuberances on the outside lobe of the brachial valve. This minor lobation is suggestive of the waves seen on the posterior lateral lobes of some Poikilosakidae, such as *Pseudoleptodus* Stehli and *Choanodus*, new genus. Similar lobation is illustrated in *Paralyttonia* Wanner and Sieverts.

The ridging of the interior is reflected on the outside of the shell. The ridges of the interior create gentle longitudinal troughs on the exterior, while the inner troughs between the ridges create gentle folds. This suggests that the ridges are formed by gentle folding of the shell. Whether or not this is initiated by a fold of the primary lamellar layer of the shell is not known. This is probably the case, as in other lyttoniids, but unsilicified material will be needed to demonstrate this.

The brachial valve is, unfortunately, poorly known and has been seen in one specimen only (Stehli, 1956a, pl. 41: fig. 10). This valve is very delicate and fragile and, because of its branching nature, may not be readily recognized. Its fragility, amorphous quality, and great rarity have all combined to prevent discovery of a loose valve. The specimen figured by Stehli and also herein shows well the lobation of the outer branches and the bifurcation of the main lobes. Undoubtedly young specimens of *Rigbyella* had a bilobed stage in which the brachial valve was cleft medially by the median ridge. With continued growth and the appearance of the lateral ridges, the two primary lobes bifurcated to form the basic adult pattern of four lobes.

### *Rigbyella girtyi* (Wanner and Sieverts)

PLATE 182: FIGURES 1-30

*Leptodus americanus* Girty, 1909: pl. 4: figs. 8, a, b.

*Paralyttonia girtyi* Wanner and Sieverts, 1935:210.

*Rigbyella girtyi* (Wanner and Sieverts) Stehli, 1956a:310.

Inasmuch as only one species of this genus is known, the important anatomical features have been amply discussed under the generic heading. Girty's specimen, the holotype (USNM 118512), is a more immature form than the ones figured by Stehli. It shows the original bilobation well and the cleft produced to accommodate the median ridge. It also shows the early stages of bifurcation

of the two primary lobes. Unfortunately, the specimen yields no details of the interior, and the brachial valve cannot be removed because it is tightly cemented to the pedicle valve.

**STRATIGRAPHIC OCCURRENCE.**—Bell Canyon Formation (Pinery and Lamar members), Capitan Formation.

**LOCALITIES.**—Pinery: USNM 725h; Lamar: AMNH 38, 430; USNM 725e, 728p, 738, 738b; Capitan?: USGS 2906 (green).

**TYPES.**—Holotype: USNM 118512; figured hypotypes: AMNH 27933/1-3, USNM 147719a-c.

**DISCUSSION.**—Stehli (1956:311) has rightly pointed out the uncertainty of the stratigraphic level of Girty's specimen. USGS 2906 is in a faulted area with uncertain stratigraphic levels. The Lamar Limestone is thought to represent deposits at the base of the great Capitan reef, including slide material from the reef. It is not known definitely, therefore, whether *Rigbyella girtyi* lived on the reef or in the waters 1500 to 2000 feet below it at its base.

### Genus *Coscinophora* Cooper and Stehli, 1955

*Coscinophora* Cooper and Stehli, 1955:469.—Termier and Termier, 1959:237.

**DIAGNOSIS.**—Large Lyttoniidae with well-formed muscle scars bounded by lateral plates and separated by myophragm; median and lateral ridges broken into series of beads (moniliseptate); terminivallate; brachial valve with lateral lobes connected by dissepiments to produce series of holes corresponding to beads of pedicle valve; cardinal process broad, thick.

**TYPE-SPECIES.**—*Coscinophora nodosa* Cooper and Stehli (1955:470, pl. 52: figs. 17-20).

**DISCUSSION.**—Cooper and Stehli established this genus on a species from the Split Tank area in the Hess Canyon Quadrangle, AMNH 500H. Their specimens showed most of the details to perfection. In describing the genus, they felt forced to abandon R. E. King's species *Lyttonia hortonii*, which is definitely a *Coscinophora*. The action was taken because of the poor quality of the King specimen. This individual has been examined further by us, during the preparation of this monograph, and has been considerably cleaned. It clearly shows all of the characters of the genus, especially

on the reverse side to that figured by King. In view of the fact that this holotype is so badly worn, without good specific characters and without a brachial valve, we cannot be sure that *L. hortonii* King and *C. nodosa* Cooper and Stehli are the same species. The two come from essentially the same stratigraphic level but on opposite sides of the mountains. It seems best, therefore, not to create a synonymy that cannot be defended.

The exterior of *Coscinophora* is very similar to that of other lyttoniids, with the exception that the species have a tendency to be subcircular or elliptical rather than spatulate, as in *Collemataria*, *Eolyttonia*, and *Leptodus*. The attachment surface is, naturally, variable, but it is generally moderately large in small specimens, but, in proportion, it is small in the largest ones. It is usually somewhat transverse. The specimens commonly lived in large clusters, with every conceivable position being occupied, to create a maximum of conflicts among the growing individuals. This leads to stunting, distortion, and internal maldevelopments.

The majority of specimens that develop in a reasonably normal form are broadly and flatly conical, but the cone is greatly distorted, so that one side is much shorter than the other. This is brought about by the development of a short cowl. In the very young the form may be a well-developed cone, but, as growth continues, the anterior side grows faster than the posterior, leaving a short cowl that may be directed anteriorly or posteriorly, depending on conditions of attachment. The usual seems to be a fairly erect cowl, but many are tilted more or less strongly anteriorly.

As usual, broad surfaces such as those presented by either side of *Coscinophora* are favorable sites of residence for a variety of sessile animals. *Coscinophora* is, therefore, a place of attachment for sponges, corals, brachiopods, and bryozoans—the hangers-on, when vigorous, resulting in the death of the host. Clusters of *Coscinophora* from USNM 709c and 710u usually are richly coated with a variety of species.

The hinge of *Coscinophora* is like that of *Eolyttonia*. In the young it is narrow and straight, consisting of an elevated ridge against which the edge of the brachial valve is fitted. In adults it may occupy a position under the cowl and not be easily visible. In these it is again a transverse slit bor-

dered posteriorly by a lip that is usually somewhat thickened and may be almost bulbous. The lip bounds a small triangular flat area that represents the zone of movement of the brachial valve while gaping. This also seems to give additional evidence that the valve was movable.

The muscle region of this genus is of unusual interest because of its fairly good development and the trace of the scars left on the valve. The muscle region is generally triangular, bounded by thin laterally divergent plates that suggest dental lamellae and might be atavistic remnants of them. At any rate, these delicate plates extend anterolaterally for a considerable distance, often to the third lateral row of beads, and commonly include some of the beads within their confines. Elongate, narrow diductor scars appear at the base of the lateral bounding ridges. Median and slightly anterior to them are larger patches of less definite shape, but of marked dendritic pattern, representing the adductor scars (Stehli, 1956a:309, pl. 42: figs. 2, 7). It is important to note that the scars indicate a symmetrical development of muscles of considerable size and strength. This is another clear evidence that *Coscinophora* could move its brachial valve to open and close the shell.

A characteristic feature of this genus is the myophragm that divides the muscles of the pedicle valve. This stands as a thin, bladelike septum, generally with the highest part toward the anterior. Its thin, bladelike character appears in the smallest specimens. The myophragm is not always connected with the median ridge or row of beads that serves as the median ridge in the genus. In many specimens the myophragm lies at a small angle to the median bead row.

The most distinctive feature of the genus is the curved rows of beads that serve in the place of the lateral septa of other Lyttoniidae. In a few specimens, especially young or youthful ones, the distal parts of the beaded rows are solid (solidiseptate), like *Eolyttonia* or *Leptodus*. In general the beads are flat plates of varying length and degree of inclination to the valve surface. In deep specimens the beads are longer and more elevated than in the flatter specimens, a situation corresponding to that in *Eolyttonia*, where deeper specimens have strongly projecting and oblique lateral septa. The beads appear to be laminar shell material protrud-

ing from a layer of fibrous, pseudopunctate shell that completely surrounds them. Interseptal ridges and longitudinal striations are developed in the older stages of some specimens. In many specimens the inner fibrous layer almost completely submerges the beads and only their distal extremities protrude. In some specimens from USNM 709c, the shell is very thick, attaining 10 mm in some individuals.

The median row of beads is constructed like that of the lateral rows, except that the beads are oriented longitudinally instead of transversely, as in the lateral rows. Unexpectedly, the elevated myophragm of the muscle area is not always in line with the median bead row, but often it extends at an angle to it, destroying the usual interior symmetry.

The brachial valve of this genus is not well known. It is a single perforated plate and is usually much more delicate than the attached valve, except for its posteromedian region. Consequently, no perfect and complete specimen of the brachial valve appears in the collection.

Few specimens preserving the cardinal process have been seen. The best-preserved specimen (paratype, USNM 124121a) has a broad, thickened but somewhat flattened boss. It is not possible to resolve this into myophores and shafts. The median ridge of the brachial valve is low and broad and is indistinct just anterior to the cardinal process. In this specimen four indistinct adductor scars appear on each side of the ridge on a flattened area just anterior to the cardinal process. In the holotype of *C. nodosa* the median ridge consists of two elevated parallel ridges with a median groove between them to about midvalve. Anterior to this point it is composed of two elevated lines, but, between them, there is a series of holes corresponding to the beaded median line of the pedicle valve.

The lateral lobes of the brachial valve are shallow, gently curved, and not complicated by internal thickening. They are connected by narrow dissepiments. In the holotype mentioned above the proximal part of the space between the lateral lobes has been filled in to form a solid posterior plate.

**DEVELOPMENT.**—Young specimens from USNM 709c give a clue as to how the species grew. As usual, the shape is variable; some specimens have

a cowl, but those that grew on flat surfaces have the cowl reflected posteriorly.

The smallest specimen (USNM 153591c) is 8 mm long by 11 mm wide. It has a fairly well-developed vallum laterally, a strong median septum apically, and has two outlobes separated by a marginal indentation and a single bead inside that. The median ridge anterior to the septum is fairly slender and consists of a long bead and an angustilobate ridge near the anterior margin. The hinge is straight on the anterior side of an arch, the sides of which form part of the attachment surface of the specimen.

A second specimen (USNM 154924a) is 14 mm in diameter and has a well-formed vallum marginally consisting of three outlobes and one bead at the first inlobe, one bead at the second inlobe, and two beads at the base of the third outlobe. This is the arrangement on the left (observer's) side of the shell. On the right side the septa are represented by single beads. The median septum is strong at the apex with two beads anterior to it. The third bead is angustilobate and occurs at the margin.

A specimen (USNM 154924b), 19 mm long by 17 mm wide, has a small cowl and a strong median septum at the apex. The median ridge consists of two elongated and thick beads. The septa on the left side consist of three beads only, representing that many septa. On the right side this specimen is aberrant in having three, possibly four, septa in the solidiseptate condition and, with this, interseptal adventitious ridges.

A third specimen, about 20 mm in diameter (USNM 154924c), is very irregular in its development. The median septum is present, and the median ridge is represented by three beads, the anterior one in the angustilobate stage. On the left side the first septal row consists of two beads, the second one is a ridge in the angustilobate stage, the third consists of two beads, and the fourth is a low septum in the angustilobate stage. Some interseptal thickening occurs at the margins.

A specimen, 17 mm long and 22 mm wide, forms a crude cone with a posteriorly directed cowl (USNM 154924d). The median septum is well formed, and the median ridge consists of two long beads. The left side has three rows consisting, in order from the posterior, of one, two, and three



beads. The bead of the first row is strongly inclined toward the anterior. On the right side the rows in the same order are two in the first, three and an incipient fourth in the second. The latter is angustilobate and is part of the vallum, which is marginally low and inconspicuous. The third row has four beads and the fourth row has three and a short angustilobate extension of the vallum.

A specimen (USNM 154924e), 25 mm long and 32 mm wide, is more normally developed. The first septal row on each side consists of an inner bead and an angustilobate extension of the vallum that is indistinct. The second row is of three beads, the outermost one a part of the vallum. The third row has six beads on the left side and three on the right. The fourth row has five beads on the left, three on the right. An indistinct fifth row of three beads appears at the anterior of the right side. The median septum is well developed and, anterior to it, is a row of four elongated beads. Most of the beads of the septal rows dip posteriorly.

It is possible to conclude from the above descriptions that the young *Coscinophora* has an incomplete vallum and that its septal walls are in the angustilobate stage. As growth continues, the inner parts of the septal wall are pinched off as beads. The septum is as strong a feature of the young as it is of the adult. It is also clear that the young *Coscinophora* is affected in its development by its habitat situation and that it seldom develops uniformly.

The collection also contains four young brachial valves, the smallest about 6 mm long (USNM 154924f). This small specimen has two lateral lobes, and, on the left side, the lobes are joined by a dissepiment that bounds one hole. On the opposite side the hole is partially formed, and the dissepiment on the outside is not formed. The median region is moderately broad, and the shell is cleft medially for about one-third the length. On the inside the median ridge is indistinct, but adductor scars appear to be visible on each side of it. The cardinal process is not distinguishable.

**STRATIGRAPHIC DISTRIBUTION.**—This genus appears first in the Decie Ranch Member of the Skinner Ranch Formation, where it forms small clusters and patches. It is also present in the Sullivan Peak Member of the Skinner Ranch Formation. It is present in the Wedin Member, low in the

Cathedral Mountain Formation. It is rare in the Split Tank area, where it occurs in the *Institella* Zone of the Cathedral Mountain Formation. The most abundant occurrence of the genus is in the Road Canyon Formation. From Sullivan Peak east to the Hess Ranch house it forms bioherms and patches, some of considerable thickness. It has not been found above the Road Canyon Formation.

### *Coscinophora hortonii* (R. E. King)

PLATE 134: FIGURES 1-5; PLATE 191: FIGURES 1-3

*Lyttonia hortonii* R. E. King, 1931:104, pl. 33: fig. 18.

The specimen designated as type in King's (1931) plate legend to this species was illustrated from one side only. The side figured is badly worn and shows moderately sized beads, about 6 or 7 in 25 mm worn down almost level with the surface between the rows. The row along the axis consists of elongate beads numbering 7 in 25 mm. Other than these facts, this side of the specimen gives little information.

On the reverse side of the holotype two individuals are attached, a large one attached by most of its surface and an immature one. The large specimen preserves somewhat more than half and thus exhibits the axis and part of the muscle region. The lateral plates and myophragm are visible but badly worn. The latter is not in line with the median row of beads. Seven beads appear in 25 mm in the anterior two rows. A remnant of the posterior flap shows this to have been directed posteriorly as usual in broadly cemented forms.

The immature specimen exhibits a median longitudinal row of beads, although the two sides are different. The right side has one continuous lateral septum and a second ridge of only one bead. The left side shows two continuous ridges and an anterior row of two beads. The surface of both specimens on this side are crusted and worn.

The holotype and the specimens attached to its reverse indicate a species of large size, more than 55 mm long and more than twice that in width. We are unable to prophesy the true form of the holotype, but it must have been somewhat elliptical for it to have had a large attachment surface and to have been fairly flat.

**STRATIGRAPHIC OCCURRENCE.**—Cathedral Mountain Formation (section 14, bed 16 of P.B. King;



according to R. E. King, 1931:71, bed 16 contains *Institella leonardensis*), Cathedral Mountain Formation (Wedin Member).

LOCALITY.—Cathedral Mountain (Wedin Member): King 7, USNM 714w.

TYPES.—Holotype: YPM 12062; figured hypotypes: USNM 150860a, b.

DISCUSSION.—We have assigned to this species a few specimens from USNM 714w, probably the same level from which King's type came.

### *Coscinophora magnifica*, new species

PLATE 182: FIGURES 35, 36; PLATE 184: FIGURES 1-8;

PLATE 185: FIGURES 1-17; PLATE 186: FIGURES 1-13;

PLATE 187: FIGURES 1-11; PLATE 188: FIGURES 15-22, 24

Large, broad, shallow cones having variable outline, usually subcircular to broadly subelliptical but elongate when distorted. Attachment surface generally small. Cowl usually short, generally erect, more rarely curved over hinge. Shell thick and strong; surface marked by concentric lines and wrinkles.

Pedicle valve interior with broad hinge; lateral plates of muscle area not well developed; myophragm thin, delicate, high anteriorly; muscle region deep, scars indistinct. Bead rows numbering about 20, strong in anterior two-thirds but becoming obscure at anterior and generally consisting of continuous ridges in terminal rows of old specimens. Beads ranging in number from 6 to 9 in 25 mm. Bead rows moderately convex anteriorly. Interseptal ridges strong in anterior third.

Brachial valve with small, thickened posterior region; lateral lobes thin and delicate; dissepiments narrow and delicate. Cardinal process not developed; median ridge consisting of 2 low ridges bounding row of holes.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 710u  |        |               |             |        |             |
| 150858a    | 88.6   | 91.3          | 19.6        | 20.0?  | 14.0        |
| 150858b    | 94.0   | 77.5          | 16.0        | 28.0   | 19.0        |
| 150858c    | 52.0   | 50.0          | ?           | 23.5   | 15.0        |
| USNM 709c  |        |               |             |        |             |
| 150856a    | 71.0   | 76.0          | 16.5        | 35.0?  | 24.0        |
| 150856b    | 47.0   | 52.0?         | 8.0         | 28.0   | 8.0         |
| USNM 721t  |        |               |             |        |             |
| 151331c    | 77.5   | 88.7          | 9.0         | 32.0?  | 24.0        |
| 151331d    | 69.2   | 69.6          | 12.0        | 39.7   | 26.5        |
| (holotype) |        |               |             |        |             |

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 706f, 709c, 710u, 716x, 720d, 721j, 721t, 721w, 721z, 722e, 724a, 724c, 724d, 726d, 726e, 732j, 732t, 732w, 733a, 733n.

DIAGNOSIS.—Large thick-shelled *Coscinophora* with beads small and generally numerous, with broadly rounded form, and thin, delicate brachial valve.

TYPES.—Holotype: USNM 151331d; figured paratypes: 150856a, 153655c, 150858b, c, 150859, 151330a, b, e-k, 151331a-c, e, f, 153591a-g, 153592a-c, 153593a-f, 153594, 153655c, 154924c; measured paratypes: 150856a, b, 150858a-c, 151331c; unfigured paratypes: 150858a, 151330c, d, 151331d, 154924a-f.

COMPARISON.—Variability in attached forms makes it difficult to compare species of this genus. *Coscinophora magnifica* usually can be recognized by its thick shell and generally rounded to transversely elliptical form, together with the great number and small size of the beads in the lateral rows. *Coscinophora nodosa* Cooper and Stehli is a somewhat smaller species with larger and flatter beads in the rows and a stouter and thicker brachial valve. *Coscinophora magnifica* differs from *C. monilifera*, new species, in the smaller size of the beads and their lesser height above the inner surface.

DISCUSSION.—This species is based on the large and fairly well-preserved specimens that come from the Road Canyon Formation just east of Sullivan Peak (USNM 709c and 710u).

When favorable circumstances permitted this species to grow unconfined, it developed a nearly circular to roundly and transversely elliptical form with short cowl and broadly conical profile. Few specimens had as favorable conditions of life as the holotype of this species. Most are distorted in some direction to produce elongate forms or exaggeratedly transverse specimens. Many specimens were not able to develop the gentle convexity of the normal specimen, but they were distorted ventrally or dorsally or both. Such distortions involved the beads of the rows in types of abnormality. General deepening of the pedicle valve led to elongation of the beads to a slatlike form, the proximal part being buried in the fibrous shell tissue. Dorsal bulging led to an opposite effect.

The cowl of this species from the Road Canyon Formation generally was short, but some specimens have the cowl unusually long. One specimen (USNM 151330), which must have been a nearly perfect cone, had a cowl 38 mm long. The surface of the cowl is marked by numerous, closely crowded pits representing pseudopunctae. About 10 layers of shell can be counted at the edge of the cowl.

The beads in the rows of this species are not as strongly protuberant as those of *C. monilifera*. This is due apparently to the great thickening of the valve floor. The shell of the holotype is about 6 mm thick near the anterior margin, but some specimens are still thicker. The beads can be seen along broken edges as laths or rods buried deep within this tissue with their rounded distal ends protruding. Toward the anterior ends of large specimens the lateral rows of beads are complicated by the interseptal ridges of *Eolyttonia* and of other lyttoniid genera. In many specimens these ridges are equal in height to the bead rows bounding them. In some specimens the ridges between the bead rows are striated parallel to the long axis of the shell, as in *Eolyttonia* and other oldhaminidine genera. The median row of beads, corresponding to the axial ridge of other lyttoniids, is seldom direct, but it is usually sinuous and the beads vary considerably in size.

The muscle scars are not usually well preserved in this species, but their details may be determined from study of a large number of specimens. Generally the lateral ridges bounding the muscle region are strongly defined. The lateral margins may be defined by a ridge or abrupt change of slope, rather than an elevated plate as in *C. nodosa*. The lateral plate in some specimens, although present, appears to have been eliminated by the deposition of adventitious shell in the depressions on its outer side. The myophragm is also variable, but it is generally so poorly preserved, because of its delicacy, that its true form is not known. It appears to rise to a sharp crest near its anterior and then taper away anteriorly.

The muscle scars are not clearly visible in many specimens of this species, but the peculiar dendritic pattern of the adductor scars illustrated by Stehli (1956a, pl. 42: figs. 2, 7) has been confirmed. The scars, however, are not elevated on a callus as in Stehli's specimens.

The brachial valve of this species is characterized by a very thick postero-axial region and very delicate lateral lobes with thin dissepiments tying them together. This is a feature strongly contrasting to the stout nature of the brachial valve of *C. nodosa*. No specimen of the brachial valve of this species showed a cardinal process. The diductor muscles must have been attached to the posterior margin or posterior edge, but no scars of attachment have been detected.

ECOLOGY.—*Coscinophora magnifica* is abundant in the Road Canyon Formation, where it occurs in bioherms composed almost wholly of this species. Specimens are abundant in the rock, but they are not usually compacted. They are loosely but fairly densely disposed, suggesting the breaking up of large patches. Few other species occur with them, at least as far as can be seen from the outcrop itself. Brachial valves are extremely rare in these deposits, suggesting some pounding by currents. These bioherms are common from the east side of Sullivan Peak to the hill north of Leonard Mountain. Many of these bioherms occur in the band of Road Canyon limestone on the west, south, and east sides of this mountain north of Leonard Mountain, which are excellent places to collect or study the species. The species was not found in the exposures of the Road Canyon Formation in the vicinity of Old Word Ranch, but a few specimens have been taken from the Sierra del Norte west of Dugout Mountain.

### *Coscinophora monilifera*, new species

PLATE 129: FIGURES 20, 21; PLATE 183: FIGURE 1;  
PLATE 188: FIGURES 1-3, 23; PLATE 189: FIGURES 1-5;  
PLATE 190: FIGURE 1

Fairly large, forming broad, shallow cone with moderately developed cowl and subcircular to sub-elliptical outline. Lateral profile moderately convex; attachment surface generally small; cowl usually overhanging hinge; shell moderately thick, exterior marked by concentric lines and wrinkles.

Pedicle valve interior with narrow hinge having broad triangular surface on cowl; lateral plates bounding muscle area obscure or not formed; myophragm low and thin, highest anteriorly; muscle marks obscure. Bead rows numbering about 17 in largest specimens; beads narrow, flattened, strongly

oblique and strongly elevated in posterior half, becoming lower anteriorly; beads variable in lateral extent, well individualized. Septal ridges between bead rows strong, variable, present mostly in anterior half. Median bead row prominent.

Brachial valve poorly known from fragments, which indicate stout platelike valve.

MEASUREMENTS (in mm).—

|            | length | maximum width | hinge width | height | cowl length |
|------------|--------|---------------|-------------|--------|-------------|
| USNM 707a  |        |               |             |        |             |
| 150865a    | 53.0   | 52.0          | 7.0         | 19.0   | 12.0        |
| 150865b    | 66.0   | 70.0          | ?           | 27.0   | 17.5        |
| 150865c    | 38.0   | 44.0          | 6.0         | 15.0   | 10.0        |
| USNM 733j  |        |               |             |        |             |
| 153590d    | 53.0   | 47.3          | 9.6         | 25.0   | 15.0?       |
| (holotype) |        |               |             |        |             |
| 153590b    | 58.7   | 63.0?         | 9.4         | 22.0   | 22.0        |
| 153590c    | 54.5   | 68.3          | 8.7         | ?      | 13.0        |

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members).

LOCALITIES.—Decie Ranch: USNM 707a, 714t; Poplar Tank: 707h, 708a; Sullivan Peak: 707d, 707g, 714y, 715j, 722-l, 733j; Skinner Ranch (base): 711d, 712p.

DIAGNOSIS.—Moderately large *Coscinophora* of moderate depth with strongly elevated beads in posterior half.

TYPES.—Holotype: USNM 153590d; figured paratypes: 153656, 153564, 153590a-c, e, f, 153595, 153597.

COMPARISON.—Individuals of this species are difficult to separate from individuals of *C. magnifica*, new species, but in the mass this species has stronger and less numerous but more elevated beads than *C. magnifica*. Lateral plates and muscle areas are less well developed, the specimens attain a smaller size, have a stronger development of the cowl, and generally tend toward deeper cups. To distinguish the two, large numbers of specimens are necessary.

This species differs from *C. nodosa* Cooper and Stehli in its greater size, lesser development of the muscle area, less prominent myophragm, and generally greater elevation of the beads.

DISCUSSION.—*Coscinophora monilifera* is not a common species and generally is confined to the Lenox Hills and Dugout Mountain, where it occurs in small clusters. Its most noteworthy features

are the strong development of the beads, which stand up strongly and obliquely above the valve floor. Adventitious shell is not as strongly developed about them as in *C. hortonii* (King) or *C. magnifica*, in which the beads are nearly buried in some specimens.

The exterior form of *C. monilifera* is variable. Some specimens develop a fairly deep conical form with a good development of the cowl. Some of these individuals also have the anterior margin bent in a dorsal direction, further emphasizing the depth and conical form. Other specimens, however, do not have any deflection of the anterior and are nearly flat in this part of the shell.

The large cluster shown on Plate 129: figures 20 and 21 is of interest because the only evidence of this species on the block from which it was etched was a few specimens. There was no hint that the bulk of the rock was composed almost wholly of this species. In addition, numerous specimens of *Geyerella* and *Tropidelasma* were intimately cemented within the mass. (See Plate 5: figure 1 for view of outcrop from which the *Coscinophora* mass was taken.)

*Coscinophora nodosa* Cooper and Stehli

PLATE 182: FIGURES 31-34

*Coscinophora nodosa* Cooper and Stehli, 1955:470, pl. 52B: figs. 17-20.

This is a rare species; only four specimens are presently known. Cooper and Stehli described it from a holotype and paratype, both of which are adults. Two additional specimens from the Split Tank area and a small individual adhering to the paratype permit some further remarks on the species. The additional specimens are all immature, but two of them exhibit the muscle scars in some detail.

The smallest of the specimens (USNM 154926) measures 14 mm long by 22 mm wide and has three bead rows, the first of one bead or short septum, the other two of two beads each on the left side but only one bead each on the right side. A fourth incipient row appears at the anterior of the right side. The median axial row consists of three beads. Lateral plates are not developed, but the myophragm is strong and is highest near its midlength and tapers to the median bead row. Diductor scars

are indistinct, but longitudinal striation just anterior to their ends indicates the position of the adductor scars. The anterior margin of this specimen is broad and sloping and is marked by numerous pustules representing pseudopunctae.

The second specimen (USNM 154925) measures 36 mm long and 32 mm wide, but neither dimension is correct because the right side and part of the anterior are broken away. Five bead rows appear on the left side, the first being partly buried in shell tissue. Five rows appear on the right side, but the fifth or anteriormost row is opposite the fifth row of the left side. This suggests that the right side is occupied by six rows. The axial bead row is sinuous, and the five beads visible are all bent toward the right side. The beads of all rows are elongate, flat, strongly oblique to the shell floor, and well separated. The muscle field is well developed and has a low lateral plate on the left side but none on the right. The diductor scars are narrow and elongate and lie at the base of the lateral ridge or the change of slope where this ridge would be. The adductor scars are small, rounded, somewhat thickened, and strongly dendritic, the one on the right side overlying a partly buried bead of the first or oldest row. The myophragm is high and thin, highest posteriorly and tapering fairly abruptly near midlength to form a low ridge between the adductor scars at the anterior end of which it terminates. The myophragm in this specimen has a broad curve to the right and terminates on the proximal bead of the second bead row on the right side. It is thus not in line with the axial median bead row.

The small specimen attached to the paratype is incomplete, but it preserves to perfection the posterior cowl, which is short and thick, and the muscle region. In this specimen the elongate diductor

scars are well formed. On the left side the distal end of the diductor scar overlies the second bead of the first bead row. The myophragm is high and delicate, the adductors are not thickened, but the dendritic markings are present, although not strongly marked.

It is an odd fact that only the smallest specimen of this species has the myophragm continuous with the axial longitudinal bead row. The beads of all rows of the holotype and paratype are flattened and somewhat lathlike, strongly oblique, with sharp edges, and strongly protruding from the floor. These characters of the beads and the nature of the muscle area are among the features distinguishing this species from the others.

Another characteristic of *C. nodosa* that separates it from *C. magnifica*, new species, is the solid character of the brachial valve, which is strong and platelike. The lateral lobes and dissepiments are strong and thick, contrasting strongly to the delicate nature of the brachial valve of *C. magnifica*. This valve has not been seen in its entirety in *C. monilifera*, new species, but the traces of it that have been encountered suggest that it is intermediate between *C. magnifica* and *C. nodosa*. Clearcut evidences of a cardinal process do not appear in any specimens or species of *Coscinophora*, but *C. nodosa* has a boss at the posterior apex that suggests this structure. It has not been possible, however, to resolve this small mass into myophores and shaft. Possibly *Coscinophora* had eliminated its cardinal process.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—AMNH 500H, 500L.

TYPES.—Holotype: USNM 124121b; paratype: 124121a; described hypotypes: 154925, 154926.

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## PLATE 24

*Isogramma* and *Roemerella*

*Isogramma lobatum*, new species: 1, Interior of a very well-preserved brachial valve, showing cardinal process with its excavated shaft and median septum and "brachial ridges,"  $\times 1$ , holotype USNM 151384; 2, dorsal view of cardinal process of same specimen,  $\times 2$  [Cathedral Mountain Formation (lower), locality USNM 702b].

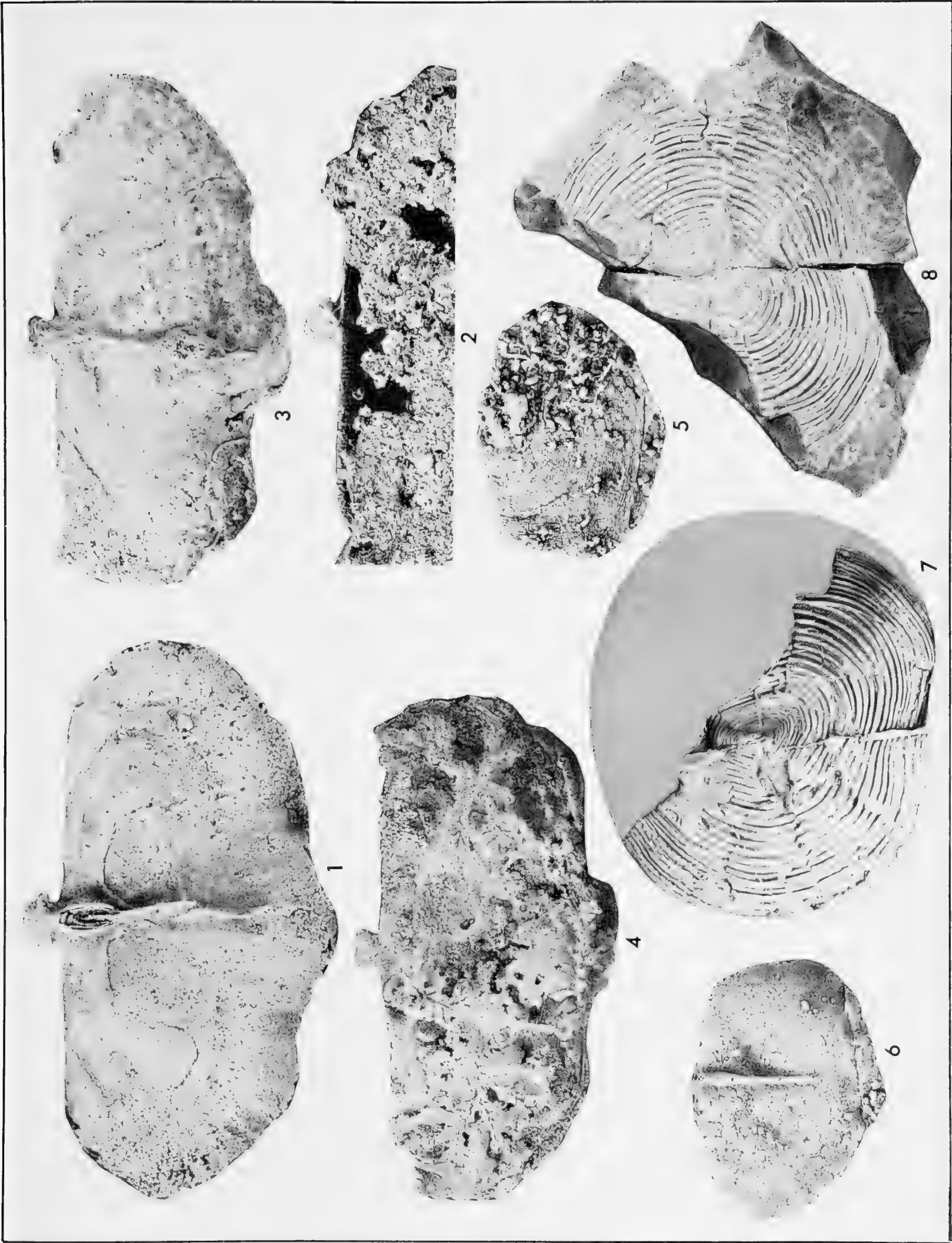
3, 4, Interior and exterior views of another large specimen,  $\times 1$ , paratype USNM 151383 [Cathedral Mountain Formation (lower), locality USNM 702].

*Isogramma* species: 5, 6, Exterior and interior of a small brachial valve,  $\times 3$ , figured specimen USNM 152570 [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 722-1].

*Roemerella gigantissima*, new species: 7, 8, Rubber replica of the exterior of an imperfect specimen and the cast from which it was made,  $\times 1$ , holotype USNM 151393a [Road Canyon Formation, locality USNM 703].



PLATE 24.—*Isogramma* and *Roemerella*.



## PLATE 25

*Isogramma*

*Isogramma* species: 1, 2, Exterior and interior views of a fragment of the pedicle valve, showing interarea, delthyrium, and trace of the muscle region,  $\times 3$ , figured specimen USNM 151388 [Cherry Canyon Formation (Getaway Member), locality USNM 728].

*Isogramma* cf. *I. lobatum*, new species: 3, 4, Interior and exterior views of a dorsal valve, showing the elongated cardinal process,  $\times 1$ , figured specimen USNM 153187a; 5, 6, interior and exterior of another brachial valve, showing excavated cardinal process shaft and median septum,  $\times 1$ , figured specimen USNM 153187e; 7, 8, interior and exterior views of a fragmentary dorsal valve, showing expanding cardinal process myophore and excavated shaft,  $\times 1$ , figured specimen USNM 153187c; 9, 10, posterior parts of two brachial valves in interior view, showing cardinal process and blister-like shaft,  $\times 1$ , figured specimens USNM 153187f and d [Cathedral Mountain Formation (lower), locality USNM 721u].

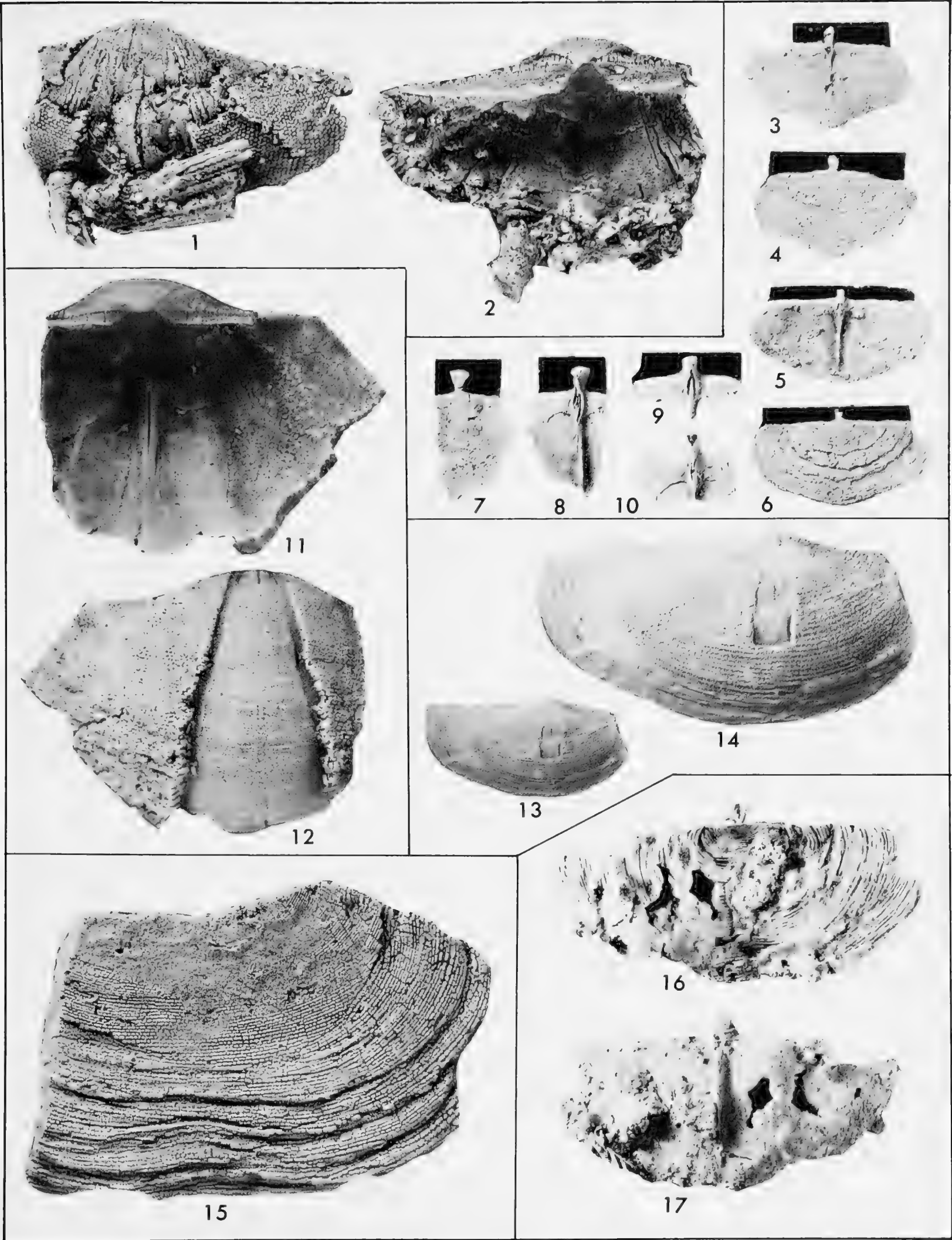
*Isogramma* species: 11, 12, Exterior and interior views of the posterior parts of an imperfect pedicle valve, showing short interarea, wide delthyrium, diductor scars, and pedicle track,  $\times 1$ , figured specimen USNM 152566 [Road Canyon Formation, locality AMNH 503 = USNM 703].

*Isogramma vidriense*, new species: 13, 14, Pedicle valve, showing long, narrow pedicle track,  $\times 1$ ,  $\times 2$ , holotype YPM 10837 [Gaptank Formation, locality King 203].

*Isogramma diabloense*, new species: 15, Exterior of a fragment, showing the ornament,  $\times 3$ , paratype USNM 151382p [Bone Spring Formation, locality USNM 725y].

*Isogramma concavum*, new species: 16, 17, Exterior and interior views of a deeply concave brachial valve,  $\times 1$ , holotype USNM 153188 [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].

PLATE 25.—*Isogramma*.



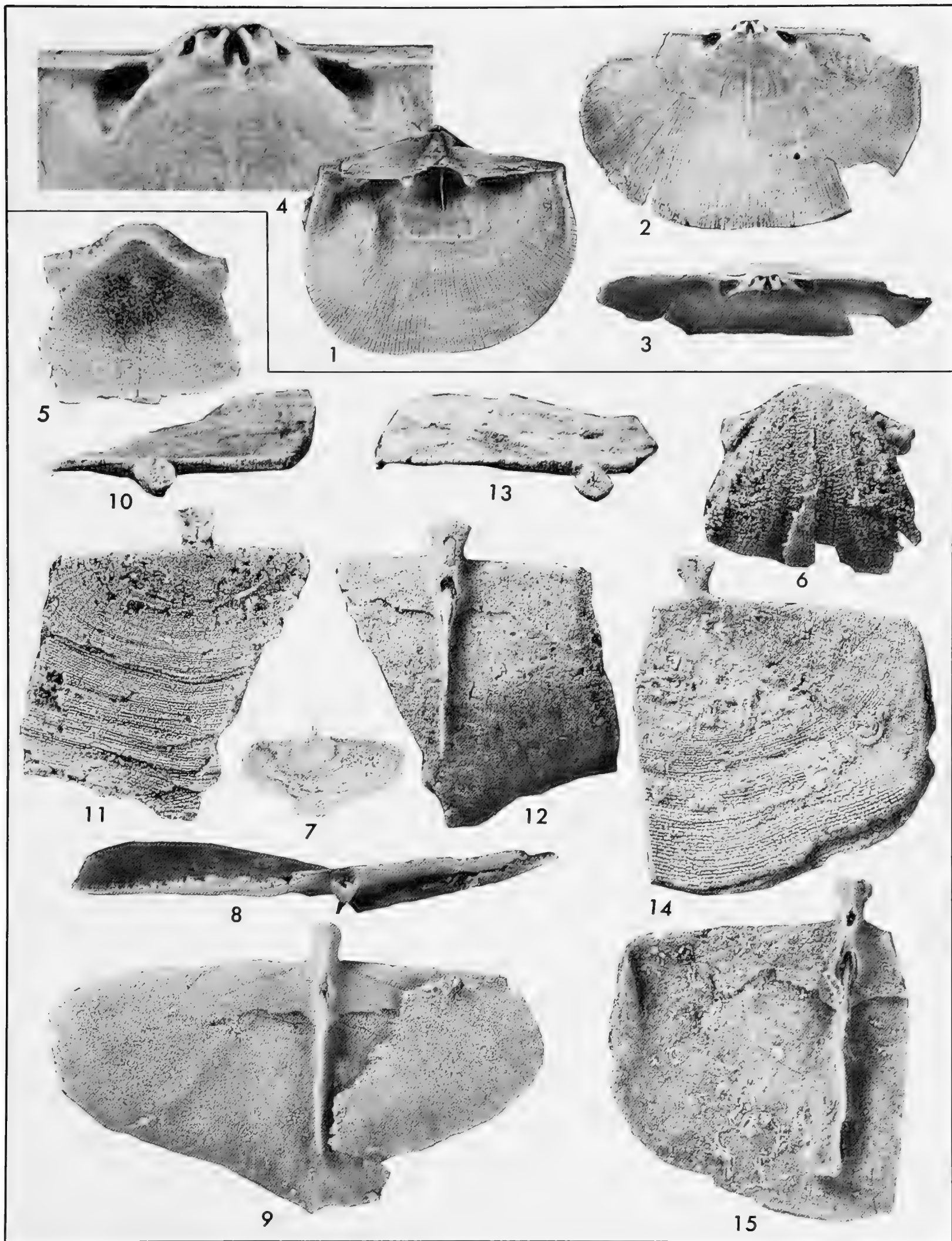
## PLATE 26

*Derbyoides* and *Isogramma*

*Derbyoides nebrascensis* Dunbar and Condra: 1, Interior of the pedicle valve, showing secondary median septum, muscle area, and pseudodeltidium,  $\times 1$ , hypotype USNM 150427c; 2, 3, interior and posterior views of the brachial valve, showing dendritic muscle field, cuplike sockets, and median ridge,  $\times 1$ , hypotype USNM 150427c; 4, cardinalia of the preceding specimen enlarged,  $\times 3$  [shale just below the Cass Limestone, locality USNM 519].

*Isogramma diabloense*, new species: 5, 6, Exterior and interior of a fragment of a pedicle valve, showing featureless interior and traces of pedicle region on the exterior,  $\times 6$ , paratype USNM 151382a; 7, exterior of a small brachial valve,  $\times 1$ , holotype USNM 151382b; 8, 9, posterior and interior of the preceding specimen,  $\times 3$ ; 10–12, posterior, exterior, and interior of a fragmentary brachial valve, showing break at junction of septum and cardinal process shaft,  $\times 3$ , paratype USNM 151382c; 13–15, posterior, exterior, and interior of another brachial valve, showing the same features,  $\times 3$ , paratype USNM 151382d [Lower Bone Spring Limestone, locality USNM 725y].

PLATE 26.—*Derbyoides* and *Isogramma*.





## PLATE 27

*Lepidocrania* and *Acanthocrania*

*Lepidocrania tardispinosa*, new species: 1, Dorsal view of a strongly lamellose specimen,  $\times 6$ , paratype USNM 151395a [Road Canyon Formation (base), locality USNM 702c].

*Acanthocrania alta*, new species: 2, 3, Dorsal and side views of a minutely spinose, elevated cone,  $\times 4$ , holotype USNM 152571 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 720g].

*Acanthocrania intermedia*, new species: 4-6, Side, dorsal and interior views of a somewhat sparsely spinose specimen,  $\times 4$ , holotype USNM 151440c; 7, exterior of another brachial valve,  $\times 4$ , paratype USNM 151440a; 8-10, dorsal, side, and interior views of a lamellose and sparsely spinose specimen,  $\times 4$ , paratype USNM 151440b [Word Formation (Willis Ranch Member), locality USNM 706].

*Acanthocrania* species: 11, Dorsal view of a small, minutely spinose individual,  $\times 6$ , figured specimen USNM 153046a [Cathedral Mountain Formation (top), locality USNM 726o].

*Acanthocrania densispina*, new species: 12, Dorsal view of a densely spinose cone,  $\times 4$ , paratype USNM 151434a; 13-15, interior, side, and exterior views,  $\times 4$ , holotype USNM 151434b [Road Canyon Formation (base), locality USNM 702c].

*Acanthocrania densispina*, new species: 16-18, Interior, side, and dorsal views of a distorted and much thickened specimen,  $\times 4$ , paratype USNM 151434c [same stratigraphy and locality as above].

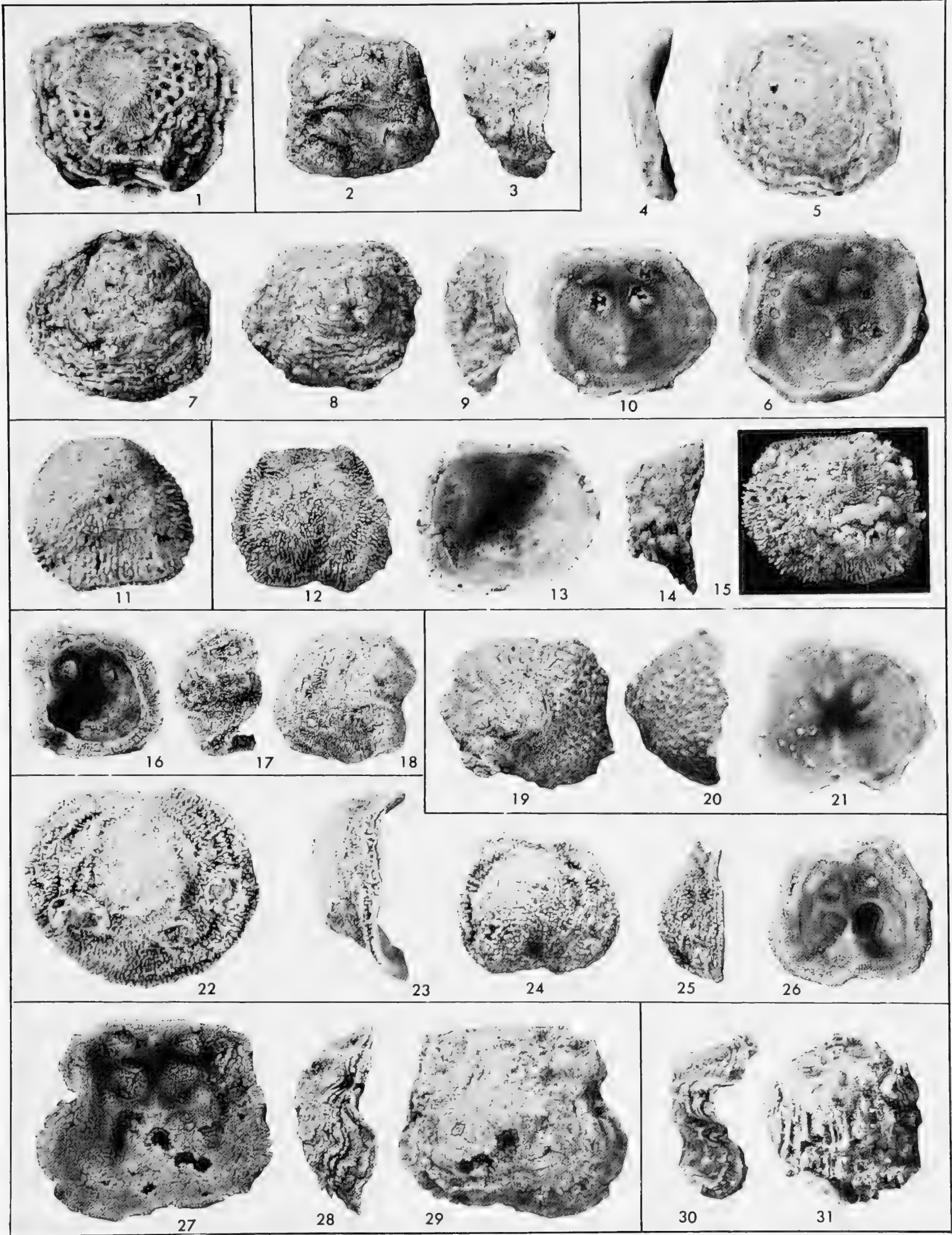
*Acanthocrania* species: 19-21, Dorsal, side, and interior views of a highly conical and coarsely spinose specimen,  $\times 4$ , figured specimen USNM 153047a [Road Canyon Formation, locality USNM 726x].

*Acanthocrania conferta*, new species: 22, 23, Dorsal and side views of a strongly spinose specimen,  $\times 6$ , paratype USNM 151429a [Cherry Canyon Formation (Getaway Member), locality AMNH 512 = USNM 728]. 24-26, Dorsal, side and interior views of the holotype with strongly marked interior,  $\times 4$ , USNM 151430b [Cherry Canyon Formation (Getaway Member), locality USNM 732].

*Lepidocrania* species: 27-29, Interior, side, and dorsal views,  $\times 4$ , figured specimen USNM 151421a [Bone Spring Formation (lower), locality USNM 728f].

*Lepidocrania* species: 30, 31, Side and dorsal views of a distorted specimen,  $\times 4$ , figured specimen USNM 151445 [Bone Spring Formation (lower), locality USNM 728h].

PLATE 27.—*Lepidocrania* and *Acanthocrania*.



## PLATE 28

*Lepidocrania, Acanthocrania, and Petrocrania*

*Lepidocrania sparsispinosa*, new species: 1, Exterior of a young brachial valve attached to productid shell,  $\times 3$ , paratype USNM 151402 [Neal Ranch Formation, locality USNM 721g].

2-4, Dorsal, side, and interior views of an average specimen,  $\times 4$ , holotype USNM 151401 [Neal Ranch Formation, locality USNM 701c].

5, 6, Dorsal and side views,  $\times 1$ , paratype USNM 151438a; 7, 8, interior and side views of the same specimen,  $\times 4$ ; 9, 10, dorsal and interior views of another paratype,  $\times 1$ , USNM 151438b; 11-13, the same specimen, showing lamellae and sparsely scattered coarse spines,  $\times 4$  [Neal Ranch Formation, locality USNM 721g].

*Acanthocrania platys*, new species: 14-16, Interior, dorsal, and side views, showing fine spines, muscle scars, and sponge or barnacle borings,  $\times 4$ , holotype USNM 151456 [Bone Spring Formation (lower), locality USNM 728f].

*Petrocrania teretis*, new species: 17-19, Interior, side, and dorsal views of a paratype,  $\times 4$ , USNM 151404c; 20-22, interior, side, and dorsal views of another paratype,  $\times 4$ , USNM 151404a [Word Formation (lens between Willis Ranch and Appel Ranch Members), locality USNM 706b].

23-25, Dorsal, side, and interior views of the holotype,  $\times 4$ , USNM 151405a [Word Formation (Willis Ranch Member, top), locality USNM 706e].

*Petrocrania* species: 26-28, Interior, side, and dorsal views, showing well impressed muscle scars,  $\times 4$ , figured specimen USNM 152579a [Cathedral Mountain Formation (lower), locality USNM 721u].

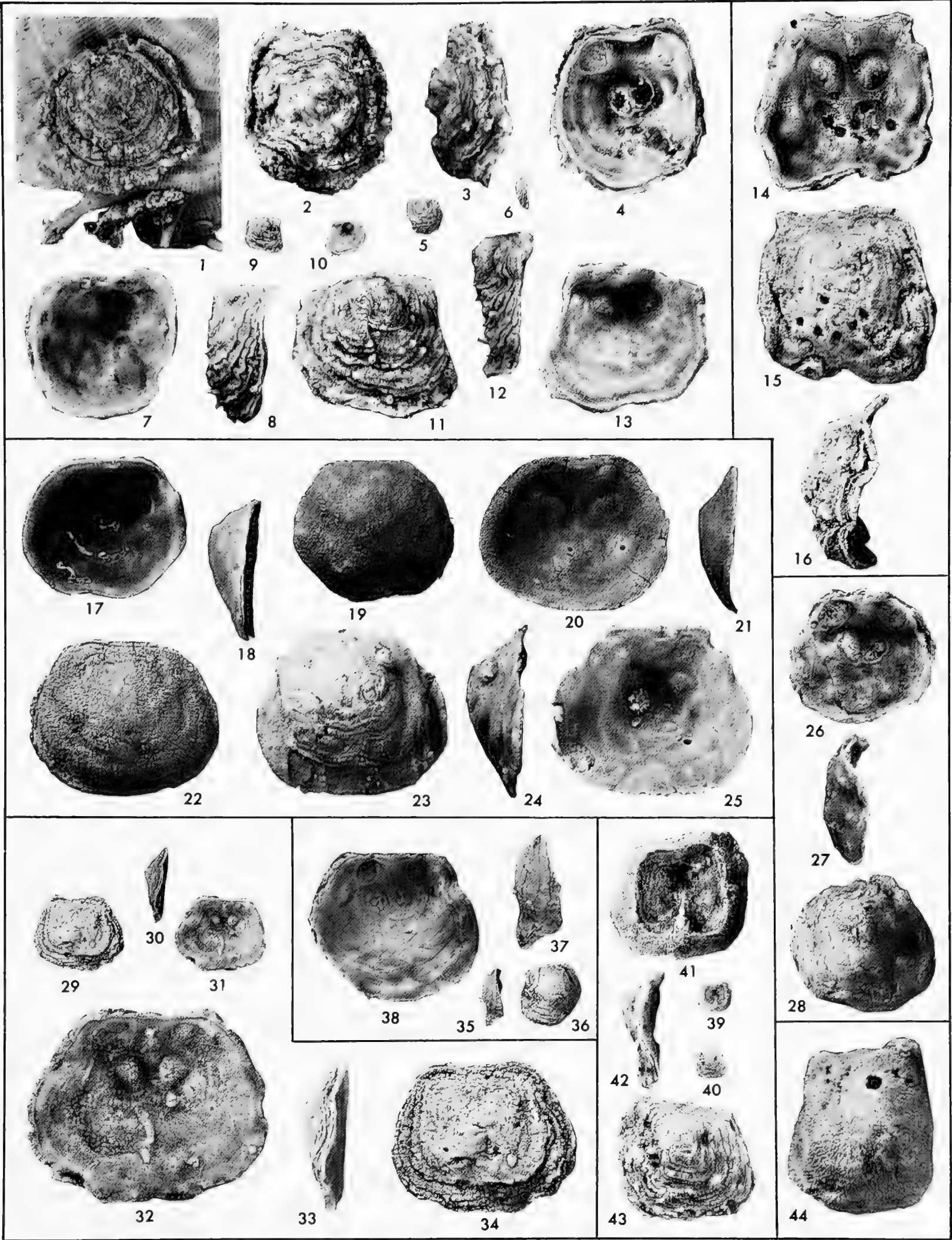
*Petrocrania diabloensis*, new species: 29-31, Dorsal, side, and interior views of a large specimen,  $\times 1$ , paratype USNM 152577; 32, interior of brachial valve showing muscle scars of paratype,  $\times 6$ ; 33, 34, side and dorsal views of the exterior,  $\times 4$  [Bone Spring Formation, locality AMNH 625].

*Petrocrania exasperata*, new species: 35, 36, Side and dorsal views of the holotype,  $\times 1$ , USNM 152578a; 37, side view,  $\times 2$ ; 38, interior, showing muscle scars,  $\times 3$  [Bell Canyon Formation (Hegler Member), locality USNM 731].

*Petrocrania septifera*, new species: 39, 40, Interior and dorsal views of the holotype,  $\times 1$ , USNM 151422; 41-43, interior, side, and dorsal views, showing anterior septum,  $\times 4$  [same stratigraphy and locality as above].

*Acanthocrania minutispinosa*, new species: 44, Dorsal view, showing mat of minute spines,  $\times 6$ , holotype USNM 151447 [Bell Canyon Formation (Hegler Member), locality AMNH 635].

PLATE 28.—*Lepidocrania*, *Acanthocrania*, and *Petrocrania*.



## PLATE 29

*Lepidocrania*

*Lepidocrania tardispinosa*, new species: 1, Exterior view of the brachial valve,  $\times 4$ , paratype USNM 151427 [Road Canyon Formation, locality USNM 706f].

2, 3, Side and dorsal views,  $\times 1$ , paratype USNM 152582c; 4-6, interior, dorsal, and side views of the same specimen,  $\times 4$ ; 7-9, side, dorsal, and interior views of the holotype,  $\times 4$ , USNM 152582a; 10-12, same views of the holotype,  $\times 1$  [Road Canyon Formation, locality USNM 721z].

13, A very young specimen,  $\times 6$ , paratype USNM 151395o [Road Canyon Formation (base), locality USNM 702c].

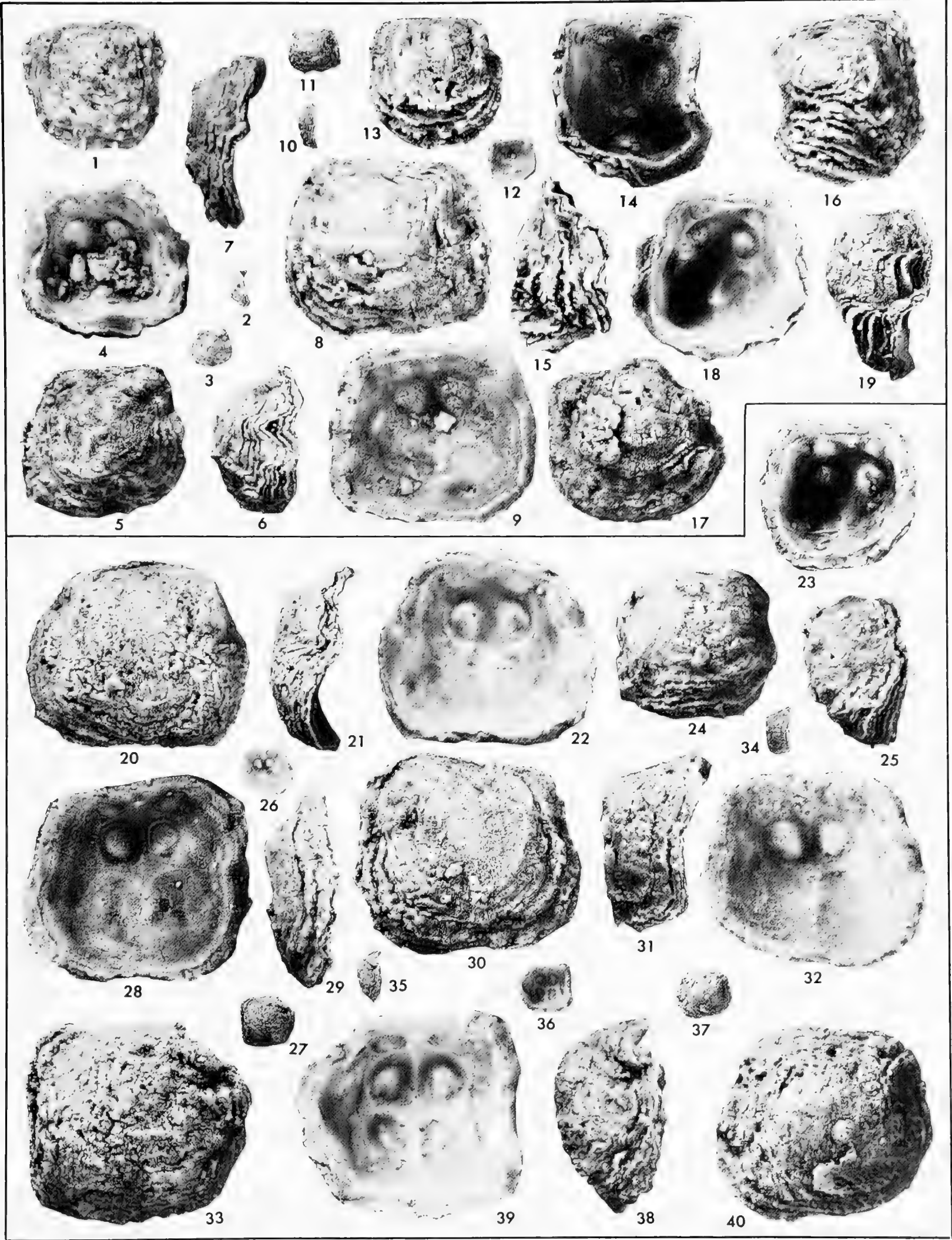
14-16, Interior, side, and dorsal views of a distorted and strongly lamellose specimen,  $\times 4$ , paratype USNM 152581 [Cathedral Mountain Formation, locality USNM 721u].

17-19, Dorsal, interior, and side views of a large brachial valve,  $\times 4$ , paratype USNM 152583 [Road Canyon Formation, locality USNM 724c].

*Lepidocrania sublamellosa*, new species: 20-22, Dorsal, side, and interior of a large specimen,  $\times 4$ , paratype USNM 151406e; 23-25, interior, dorsal, and side views of a thickened specimen,  $\times 4$ , paratype USNM 151406f; 26-30, interior and dorsal views,  $\times 1$ , and interior, side, and dorsal views of a large somewhat worn specimen,  $\times 4$ , paratype USNM 151406c; 31-34, side, interior, and dorsal views,  $\times 4$ , and side view,  $\times 1$ , of another paratype, USNM 151406b; 35-37, side, interior, and dorsal views of the holotype,  $\times 1$ , USNM 151406a; 38-40, the same views of the holotype, showing the muscle scars of the brachial valve,  $\times 4$  [Word Formation (Willis Ranch Member, top), locality USNM 706e].



PLATE 29.—*Lepidocrania*.



## PLATE 30

*Niviconia*, *Derbyia*, *Tropidelasma*, *Diplanus*, *Acanthocrania*, and *Lepidocrania*

*Niviconia globosa* (R. E. King): 1, View of the interarca of a large pedicle valve, showing the narrow, elevated fold on the pseudodeltidium,  $\times 1$ , hypotype USNM 153048 [Cathedral Mountain Formation (lower), locality USNM 702b].

*Derbyia carteri*, new species: 2-6, Ventral, posterior, dorsal, anterior, and side views,  $\times 1$ , paratype USNM 151020b [Neal Ranch Formation (bed 4), locality USNM 701d].

*Tropidelasma* species 4: 7, 8, Exterior and side views of the brachial valve,  $\times 1$ , figured specimen 152603a; 9, 10, side and interior views of another brachial valve, showing the long cardinal process,  $\times 1$ , figured specimen USNM 152603b [Cathedral Mountain Formation (lower), locality USNM 721u].

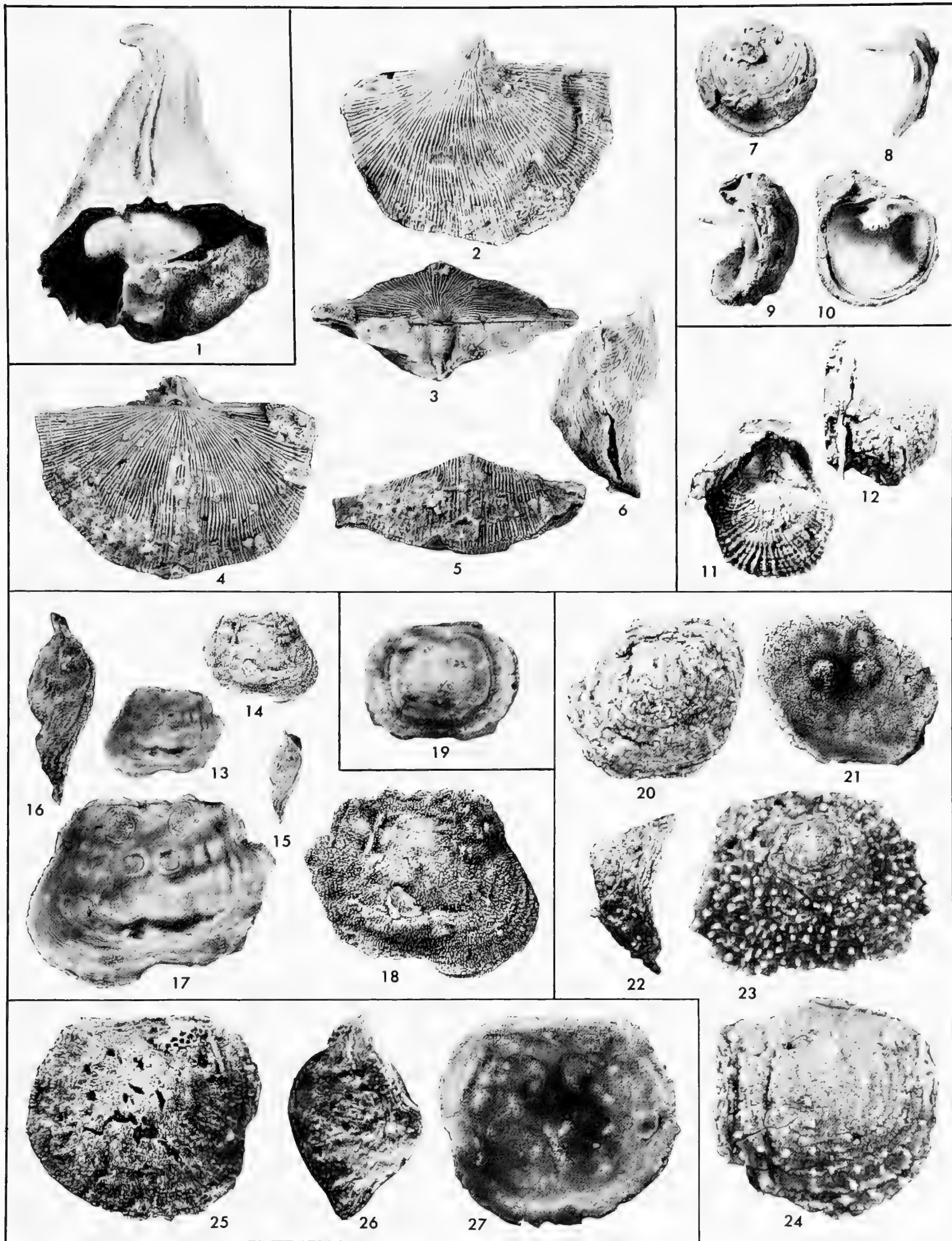
*Diplanus* cf. *D. rarus*, new species: 11, Dorsal view of a large specimen attached to a lyttoniid shell,  $\times 1$ , figured specimen 153049a; 12, side view of another specimen similarly attached,  $\times 1$ , figured specimen USNM 153049b [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].

*Acanthocrania vasta*, new species: 13-15, Interior, dorsal, and side views of a large dorsal valve,  $\times 1$ , holotype USNM 152573; 16-18, side, interior, and dorsal views of the holotype, showing the small muscle scars,  $\times 2$  [Bell Canyon Formation (Hegler Member), locality USNM 731].

*Lepidocrania tardispinosa*, new species: 19, Immature brachial valve in dorsal view, showing beginnings of lamellae,  $\times 6$ , paratype USNM 151395j [Road Canyon Formation (base), locality USNM 702c].

*Acanthocrania regularis*, new species: 20-22, Dorsal, interior, and side views, showing thickened muscle scars,  $\times 4$ , holotype USNM 152572c; 23, dorsal view of another specimen, showing the coarsely spinose surface,  $\times 4$ , paratype USNM 152572a; 24, dorsal view of another paratype from which most of the spines have been stripped,  $\times 4$ , USNM 152572b [Bell Canyon Formation (Rader Member), locality USNM 725f].

*Acanthocrania intermedia*, new species: 25-27, Dorsal, side, and interior views of a paratype,  $\times 4$ , USNM 151442a [Word Formation (China Tank Member), locality USNM 702c].

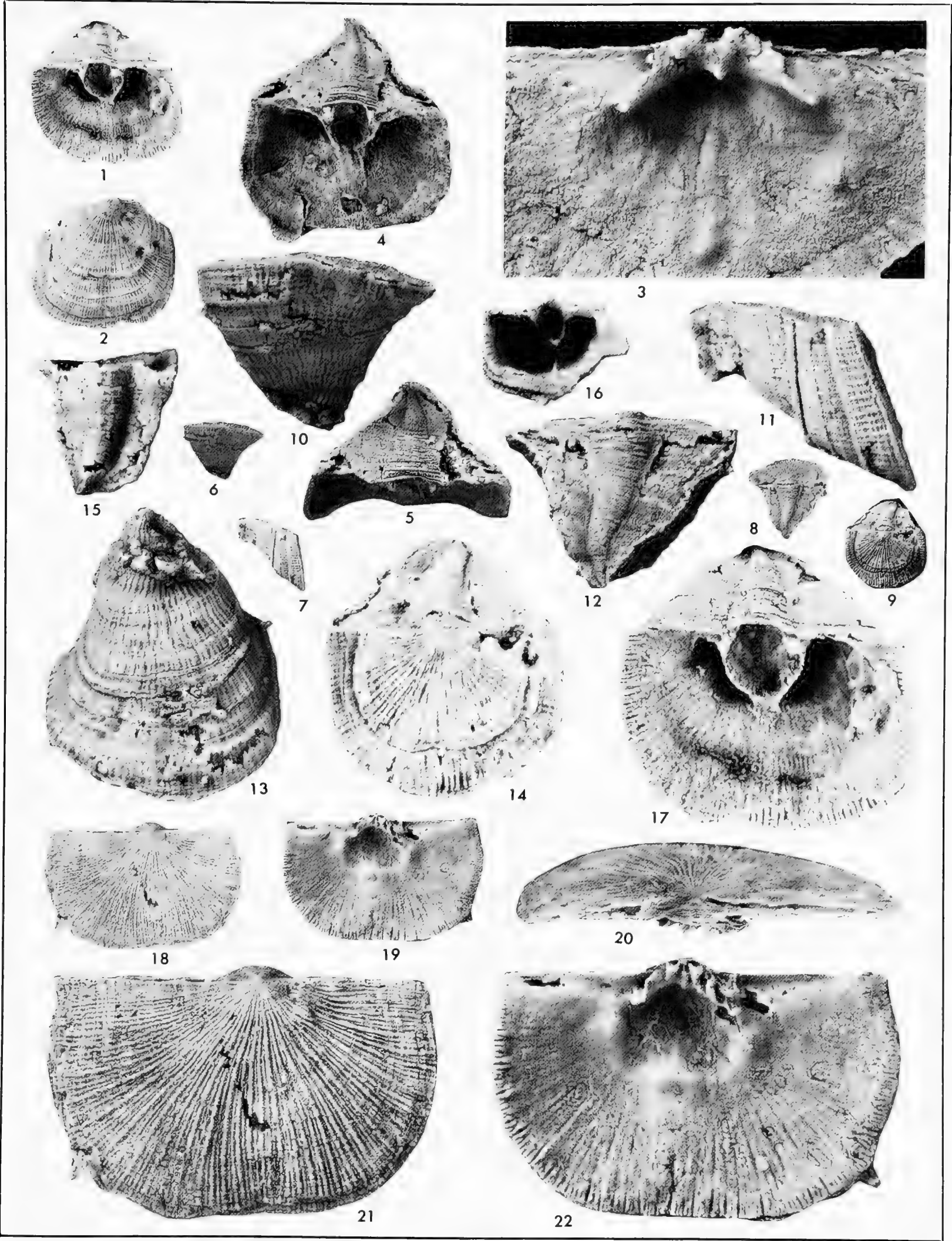
PLATE 30.—*Niviconia*, *Derbyia*, *Tropidelasma*, *Diplanus*, *Acanthocrania*, and *Lepidocrania*.

**PLATE 31***Hypopsia*

*Hypopsia versuta*, new species: 1, 2, Interior and exterior of a pedicle valve,  $\times 1$ , paratype USNM 152587d; 17, interior of the preceding specimen, showing spondylium,  $\times 2$ ; 3, cardinalia of the brachial valve,  $\times 5$ , paratype USNM 152587k; 4, 5, interior and posterior of a large pedicle valve with spondylium attached to floor,  $\times 1$ , paratype USNM 152587a; 6–9, anterior, side, posterior, and dorsal views of a small, complete individual,  $\times 1$ , holotype USNM 152587i; 10–14, anterior, side, posterior, ventral, and dorsal views of the holotype,  $\times 3$ ; 15, 16, posterior and interior of a long, narrow pedicle valve,  $\times 3$ , paratype USNM 152587j; 18, 19, exterior and interior of a brachial valve,  $\times 1$ , paratype 152587f; 20–22, posterior, exterior, and interior of the preceding,  $\times 2$  [Neal Ranch Formation (bed 2 of P. B. King), locality USNM 701].



PLATE 31.—*Hypopsia*.





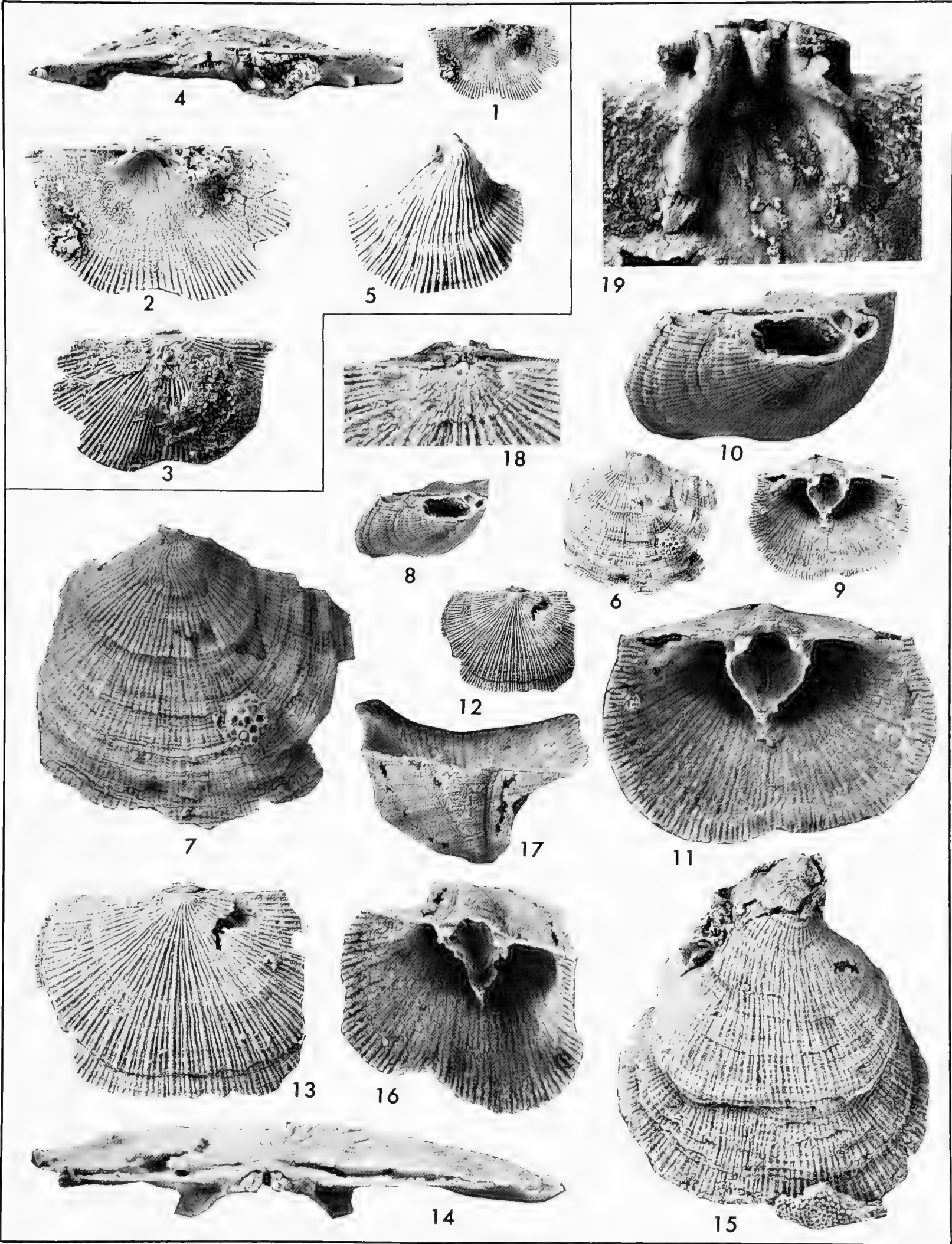
## PLATE 32

*Schuchertella* and *Hypopsia*

*Schuchertella subvexa*, new species: 1, Interior of a brachial valve,  $\times 1$ , paratype USNM 152589i; 3, exterior of the same,  $\times 1.5$ ; 2, interior of the same, showing cardinalia,  $\times 2$ ; 4, posterior of same showing chilidium,  $\times 3$ ; 5, exterior of a well-preserved pedicle valve,  $\times 2$ , paratype USNM 152589e [Neal Ranch Formation (bed 2 of P. B. King), locality USNM 701].

*Hypopsia versuta*, new species: 6, 7, Exterior of the pedicle valve,  $\times 1$ ,  $\times 2$ , paratype USNM 152587-1; 8, 9, partial side and interior views of a pedicle valve, showing spondylium,  $\times 1$ , paratype USNM 152587b; 10, 11, same views as preceding, but  $\times 2$ ; 12, 13, exterior of a brachial valve,  $\times 1$ ,  $\times 2$ , paratype USNM 152587m; 14, posterior of same, showing cardinal process and chilidium,  $\times 4$ ; 15, exterior of a pedicle valve,  $\times 2$ , paratype USNM 152587c; 16, 17, interior and posterior views of a pedicle valve,  $\times 2$ , paratype USNM 152587e; 18, posterior of a brachial valve, showing cardinal process,  $\times 3$ , paratype USNM 152587k; 19, cardinalia of an obese brachial valve;  $\times 4$ , paratype USNM 152587n [Neal Ranch Formation (bed 2 of P. B. King), locality USNM 701].

PLATE 32.—*Schuchertella* and *Hypopsia*.

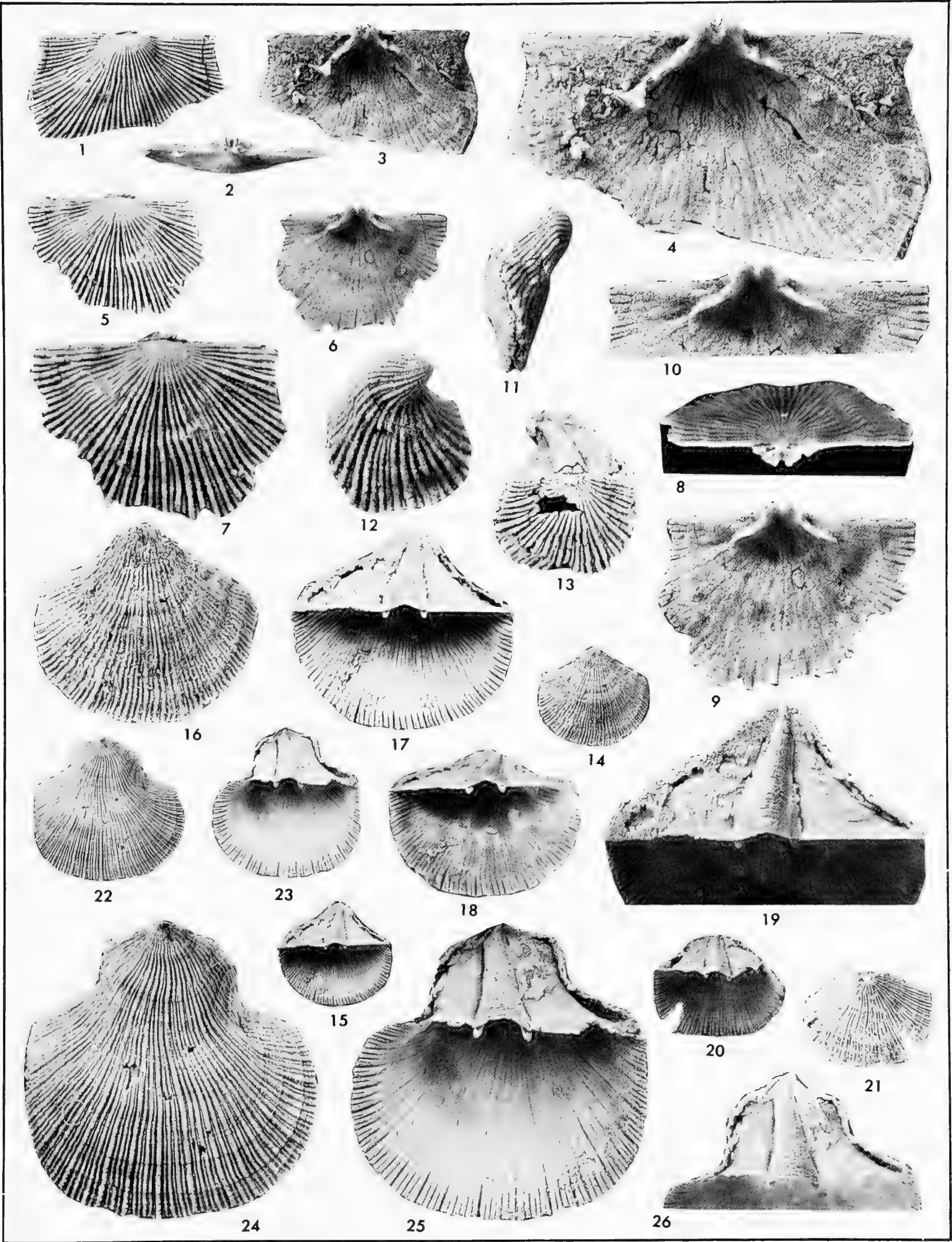


## PLATE 33

*Schuchertella*

*Schuchertella subvexa*, new species: 1, 2, Exterior and posterior of a brachial valve,  $\times 1.5$ , paratype USNM 152589j; 3, 4, same specimen enlarged to show the cardinalia,  $\times 2$  and  $\times 4$ ; 5, 6, exterior and interior of another brachial valve,  $\times 2$ , paratype USNM 152589k; 7-9, exterior, posterior, and interior of the same specimen,  $\times 3$ ; 10, cardinalia of the preceding, showing laterally extended supporting plates,  $\times 4$ ; 11-13, side, ventral, and dorsal views of an immature, complete specimen,  $\times 4$ , paratype USNM 152589b; 14, 15, exterior and interior of a pedicle valve,  $\times 1$ , paratype USNM 152589f; 16, 17, same views of same specimen,  $\times 2$ ; 18, interior of same specimen, tilted to show absence of dental plates,  $\times 1.5$ ; 19, interarea of preceding specimen, showing pseudodeltidium,  $\times 4$ ; 20, 21, interior and exterior of another pedicle valve,  $\times 1$ , paratype USNM 152589g; 22, 23, exterior and interior of a large pedicle valve,  $\times 1$ , holotype USNM 152589h; 24, 25, same views of holotype,  $\times 2$ ; 26, interarea of the holotype in full view,  $\times 2$  [Neal Ranch Formation (bed 2 of P. B. King) locality USNM 701].

PLATE 33.—*Schuchertella*.

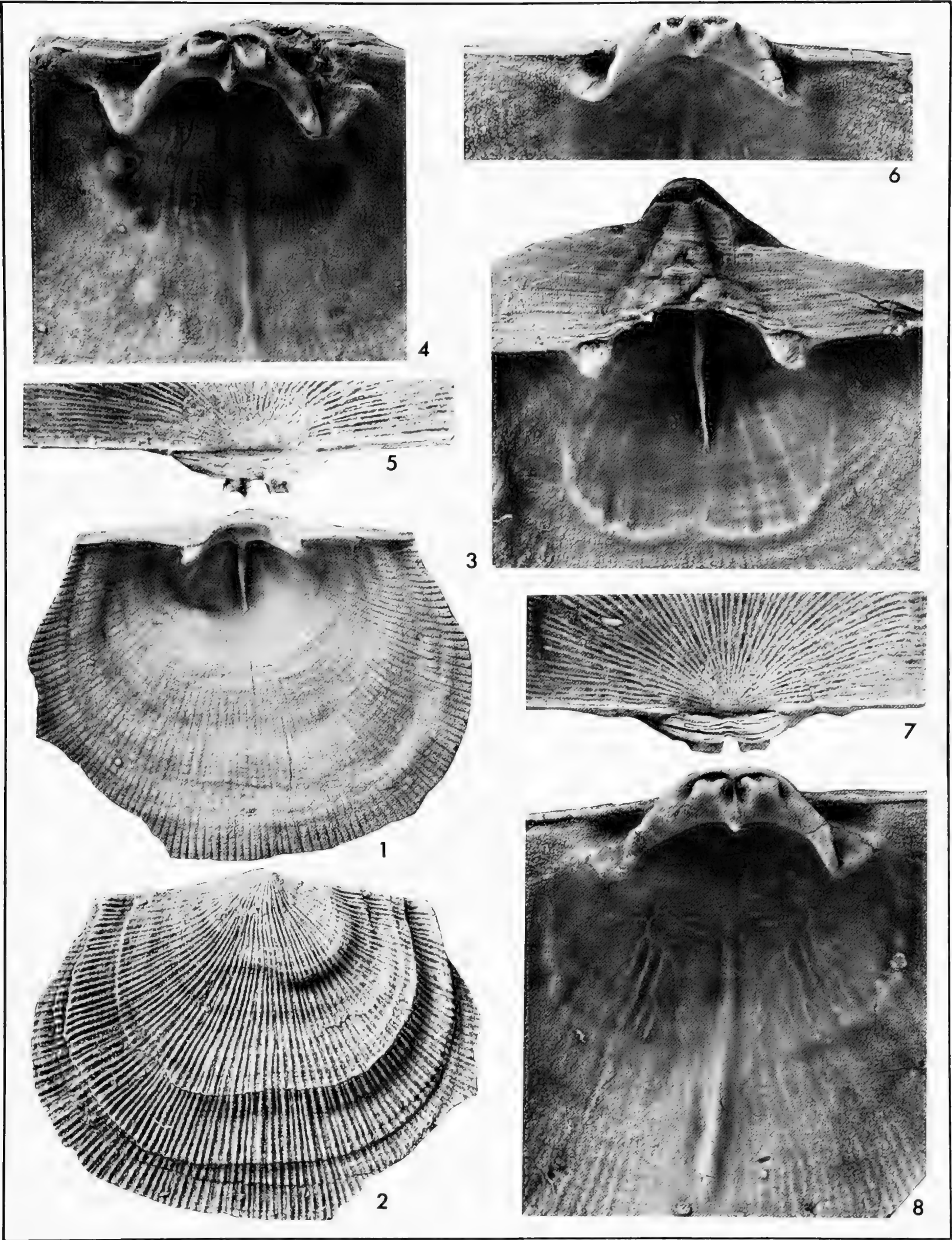


**PLATE 34***Derbyoides*

*Derbyoides nebrascensis* Dunbar and Condra: 1, 2, Interior and exterior of a pedicle valve, showing the secondary median ridge,  $\times 2$ , hypotype USNM 150427a; 3, view of the pseudo-deltidium and secondary median ridge of another pedicle valve,  $\times 3$ , hypotype USNM 150427c; 4, 5, interior and posterior views of the cardinalia of a brachial valve, showing strong chilidium, indistinct median ridge, sockets, and dentifers,  $\times 3$ , hypotype USNM 150427f; 6, interior view of the cardinalia,  $\times 3$ , hypotype USNM 150427g; 7, 8, posterior and interior views of another specimen, showing cardinalia and the dendritic pattern of the muscle scars,  $\times 3$ , hypotype USNM 150427h [shale just below the Cass limestone, locality USNM 519].



PLATE 34.—*Derbyoides*.



## PLATE 35

*Ombonia and Derbyoides*

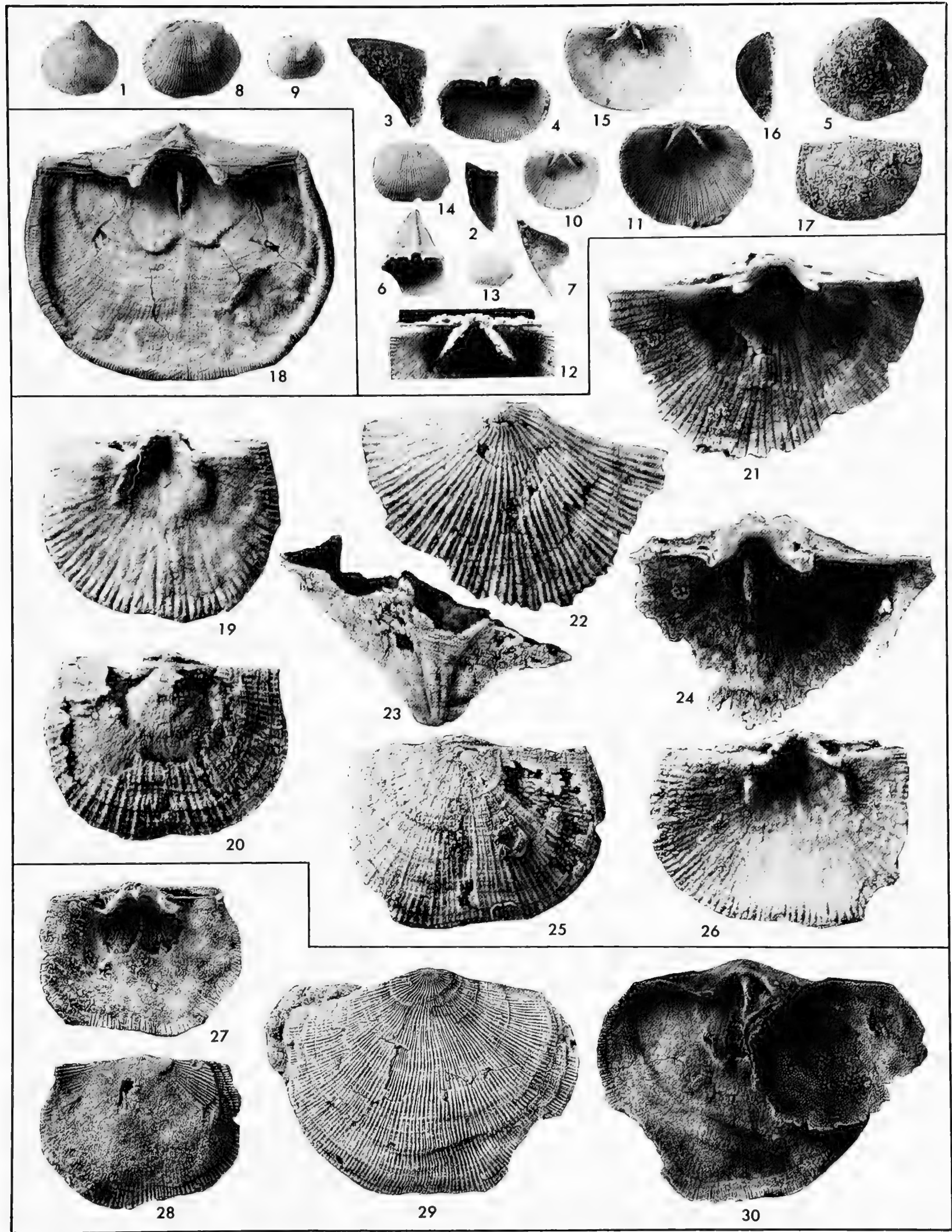
*Ombonia invecta*, new species: 1, 2, Exterior and side views of a young pedicle valve,  $\times 1$ , paratype USNM 150995d; 3–5, side, interior, and exterior views of a large pedicle valve,  $\times 1$ , holotype USNM 150995a; 6, 7, posterior and side views of a smaller pedicle valve,  $\times 1$ , paratype USNM 150995i; 8, 9, exterior of a small brachial valve,  $\times 2$ ,  $\times 1$ , paratype USNM 150995j; 10, 11, interior of a brachial valve,  $\times 2$ ,  $\times 3$ , paratype USNM 150995k; 12, posterior of another brachial valve interior, showing the long, widely divergent crismata supporting the cardinal process,  $\times 4$ , paratype USNM 150995–1; 13, 14, exterior of a small brachial valve,  $\times 1$ ,  $\times 2$ , paratype USNM 150995m; 15–17, interior side and exterior views of a large brachial valve,  $\times 1$ , paratype USNM 150995c [Road Canyon Formation, locality USNM 702d].

*Derbyoides nebrascensis* Dunbar and Condra: 18, Interior of the pedicle valve, showing muscle field and strong, secondary median ridge,  $\times 1$ , hypotype USNM 150427b [shale just below the Cass Limestone, locality USNM 519, 2 mi NW Nehawka, Nebraska].

*Derbyoides marathonensis*, new species: 19, 20, Interior and exterior of a brachial valve,  $\times 2$ , paratype USNM 150425c; 21–23, interior, exterior, and posterior views of a ventral valve,  $\times 2$ , holotype USNM 150425a; 24, interior of another pedicle valve, showing a thick median ridge,  $\times 2$ , paratype USNM 150425d; 25, 26, exterior and interior of another brachial valve,  $\times 2$ , paratype USNM 150425c [Neal Ranch Formation (Gray Limestone of P. B. King), locality USNM 701].

*Derbyoides dunbari*, new species: 27, 28, Interior and exterior of the brachial valve,  $\times 1$ , paratype USNM 150424b; 29, 30, exterior and interior of the pedicle valve, showing secondary median ridge,  $\times 1$ , holotype USNM 150424a [same stratigraphy and locality as above].

PLATE 35.—*Ombonia* and *Derbyoides*.



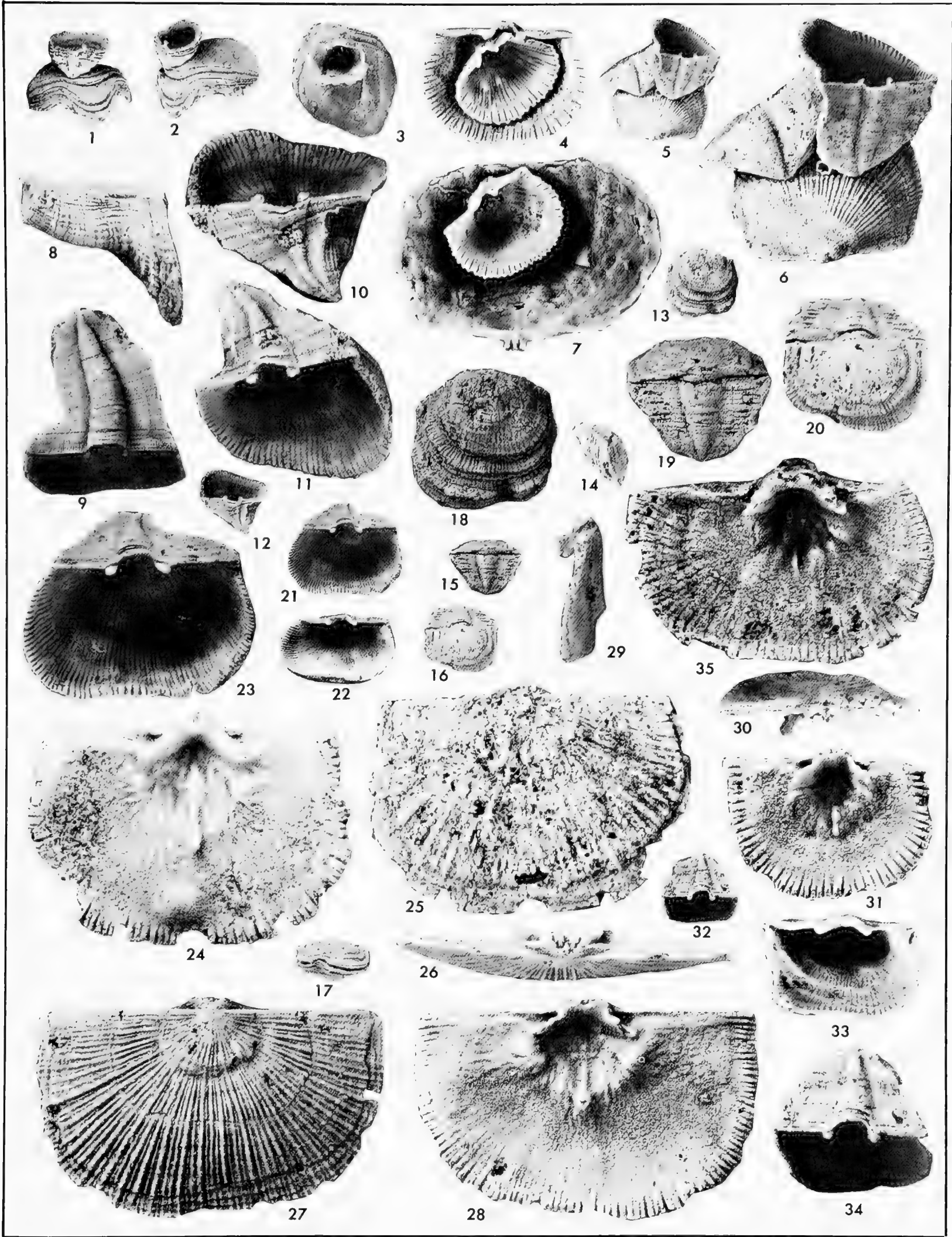
## PLATE 36

*Goniarina*

*Goniarina permiana* (Stehli): 1–3, specimen attached by its beak to a *Composita* valve; posterior, side and interior views,  $\times 1$ , hypotype USNM 153514a; 4, one individual attached to the inside of the pedicle valve of another individual,  $\times 3$ , hypotype USNM 153514b; 5, 6, pedicle valve with two others attached,  $\times 1$ ,  $\times 2$ , hypotype USNM 153514d; 7, pedicle valve attached to the brachial valve of *Elliottella*,  $\times 3$ , hypotype USNM 153514c; 8, 9, side and posterior views of pedicle valve with elongated beak and well-developed pseudodeltidium,  $\times 3$ , hypotype USNM 153514e; 10, 11, posterior and interior of another pedicle valve of more normal proportions,  $\times 3$ , hypotype USNM 153514f; 12, posterior of same,  $\times 1$ ; 13–17, ventral, side, posterior, dorsal, and anterior views of a complete specimen,  $\times 1$ , hypotype USNM 150405t; 18–20, ventral, posterior, and dorsal views of the preceding,  $\times 2$ ; 21, 22, interior and tilted views of a pedicle valve,  $\times 1$ , hypotype USNM 150405q; 23, interior of the same,  $\times 3$ ; 24, 25, interior and exterior of a brachial valve having a cyst and boring,  $\times 4$ , hypotype USNM 153514g; 26–28, posterior, exterior, and interior of a large brachial valve,  $\times 4$ , hypotype USNM 150405a; 29–31, side, posterior, and interior views of a small brachial valve, showing well-developed cardinalia,  $\times 4$ , hypotype USNM 153514h; 32–34, posterior,  $\times 1$ , and interior and posterior,  $\times 2$ , of a pedicle valve, hypotype USNM 153514j; 35, interior of dorsal valve, showing cardinalia,  $\times 4$ , hypotype USNM 150514i [Bone Spring Formation, locality USNM 728f].



PLATE 36.—*Goniarrina*.





## PLATE 37

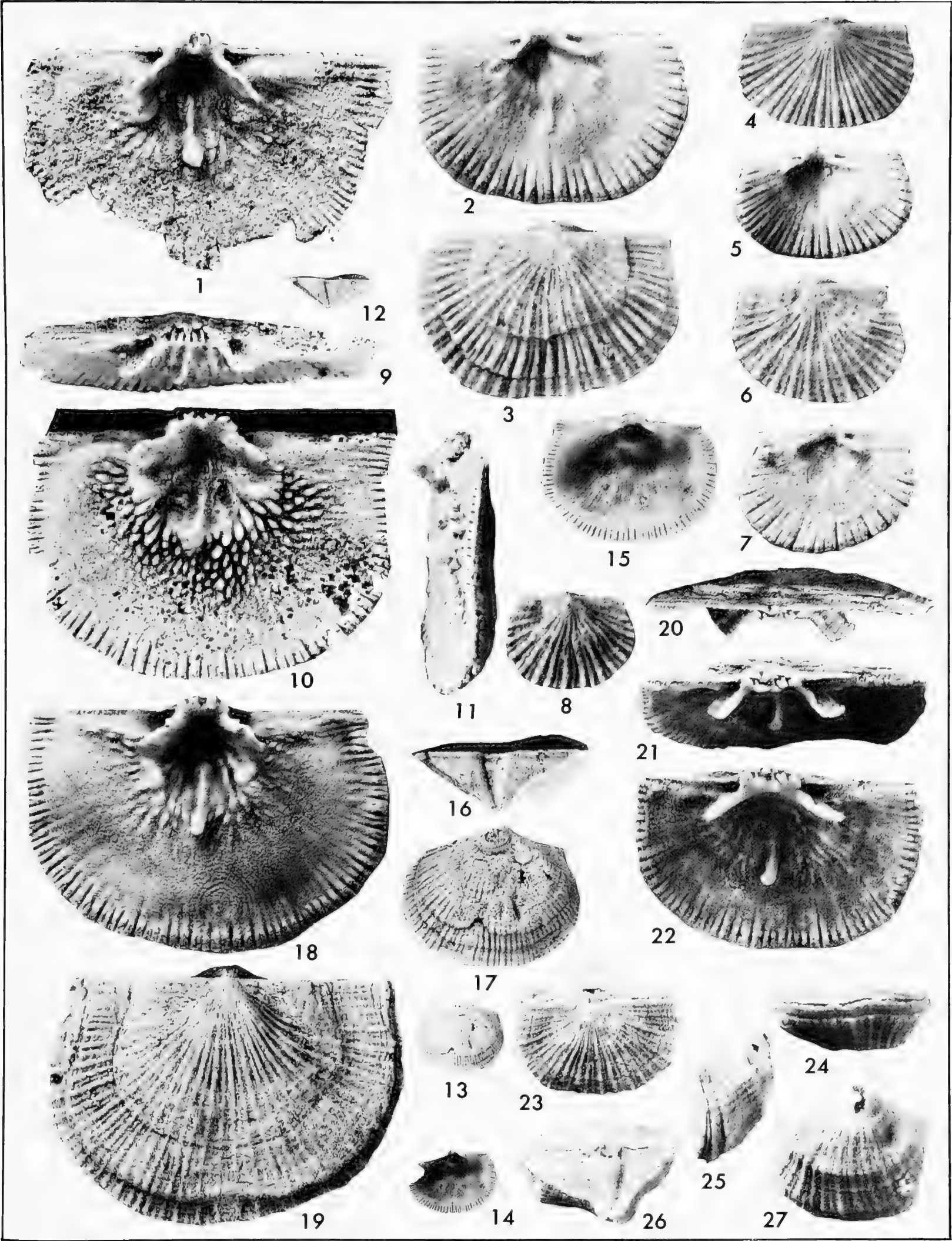
*Goniarina*

*Goniarina permiana* (Stehli): 1, Interior of a large brachial valve, showing cardinalia and thickened median ridge,  $\times 4$ , hypotype USNM 153514k; 9–11, posterior, interior, and side views of a thickened brachial valve, showing cardinalia and great development of taleolae,  $\times 4$ , hypotype USNM 153514–l; 12–14, posterior, ventral, and interior views of a pedicle valve,  $\times 1$ , hypotype USNM 153514m; 15–17, tilted interior, posterior, and ventral views of the preceding,  $\times 2$  [Bone Spring Formation, locality USNM 728f].

2, 3. Interior and exterior of an immature brachial valve,  $\times 6$ , hypotype USNM 153515a; 4, 5, exterior and interior of a smaller specimen than the preceding,  $\times 6$ , hypotype USNM 153515b; 6, 7, a still smaller specimen,  $\times 6$ , hypotype USNM 153515c; 8, exterior of the smallest specimen,  $\times 6$ , hypotype USNM 153515d; 18, 19, interior and exterior of a well-preserved brachial valve,  $\times 4$ , hypotype USNM 153515e; 20–22, posterior, tilted and interior views of a thickened brachial valve,  $\times 4$ , hypotype USNM 153515f [Bone Spring Formation, locality USNM 728h].

23–27, Dorsal, anterior, side, posterior, and ventral views of a complete specimen,  $\times 2$ , hypotype USNM 153516 [Bone Spring Formation, locality USNM 725c].

PLATE 37.—*Goniarrina*.

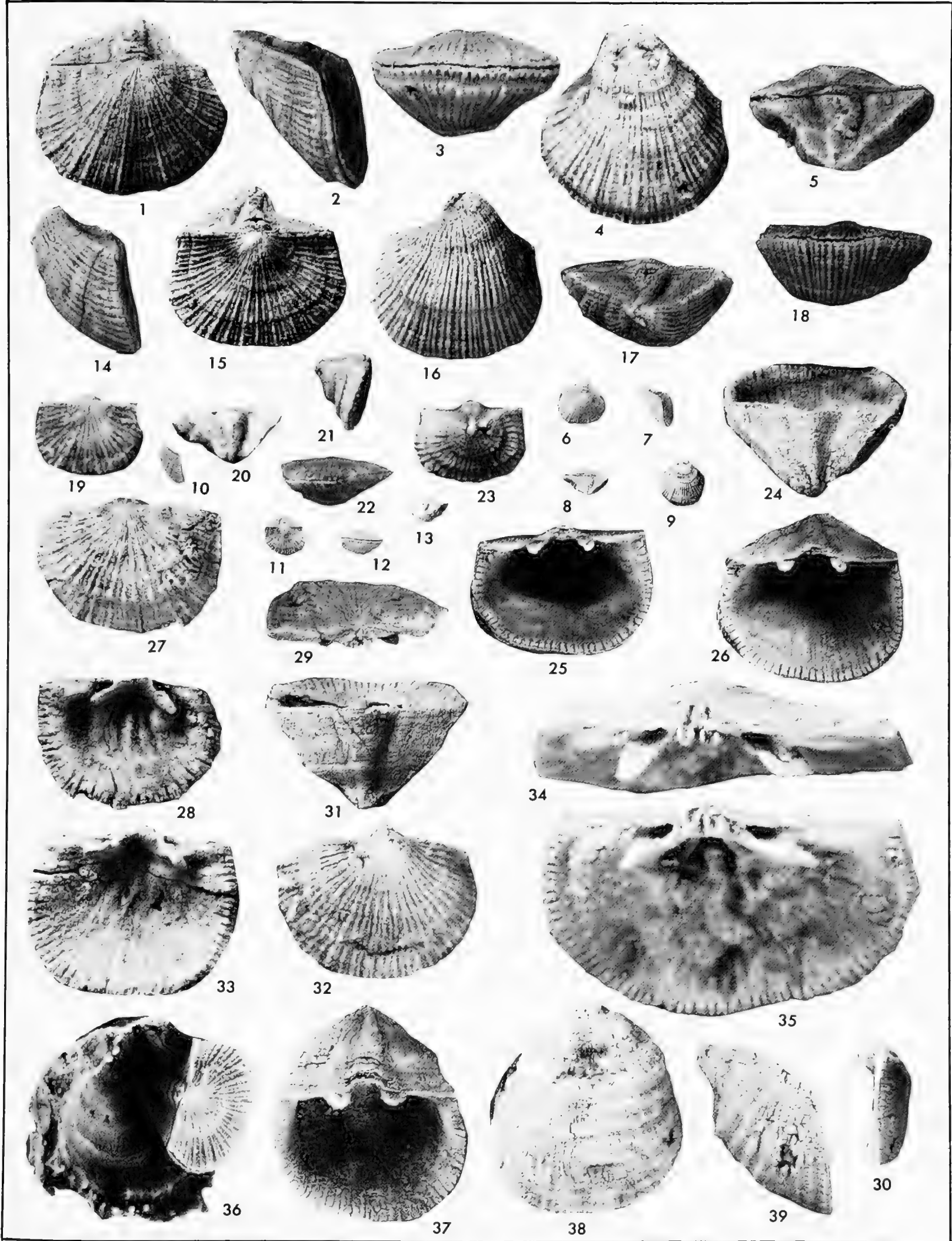


## PLATE 38

*Goniarina*

*Goniarina pyelodes*, new species: 1–5, Dorsal, side, anterior, ventral, and posterior views,  $\times 4$ , holotype USNM 150411g; 6–9, dorsal, side, posterior, and ventral views of the holotype,  $\times 1$ ; 10–13, side, dorsal, anterior, and posterior views of a large adult,  $\times 1$ , paratype USNM 150411f; 14–18, side, dorsal, ventral, posterior, and anterior views of the same specimen,  $\times 4$ ; 19–23, dorsal, posterior, side, anterior, and ventral views of a small specimen,  $\times 4$ , paratype USNM 150411d; 24–26, posterior, tilted interior and interior views of the pedicle valve,  $\times 4$ , paratype USNM 150411i; 27–30, exterior, interior, posterior, and side views of a brachial valve,  $\times 4$ , paratype USNM 150411j; 31, 32, posterior and exterior of a pedicle valve,  $\times 4$ , paratype USNM 150411k; 33, interior of a brachial valve,  $\times 4$ , paratype USNM 150411–l; 34, 35, posterior and interior of another brachial valve,  $\times 6$ , showing cardinalia, paratype USNM 150411m; 36, valve of *Teguliferina* with attached *Goniarina pyelodes*,  $\times 3$ , paratype USNM 150410; 37–39, interior, ventral, and side views of a large pedicle valve, showing teeth and pseudodeltidium,  $\times 4$ , paratype USNM 150411n [Neal Ranch Formation, locality USNM 701k].

PLATE 38.—*Goniarrina*.



## PLATE 39

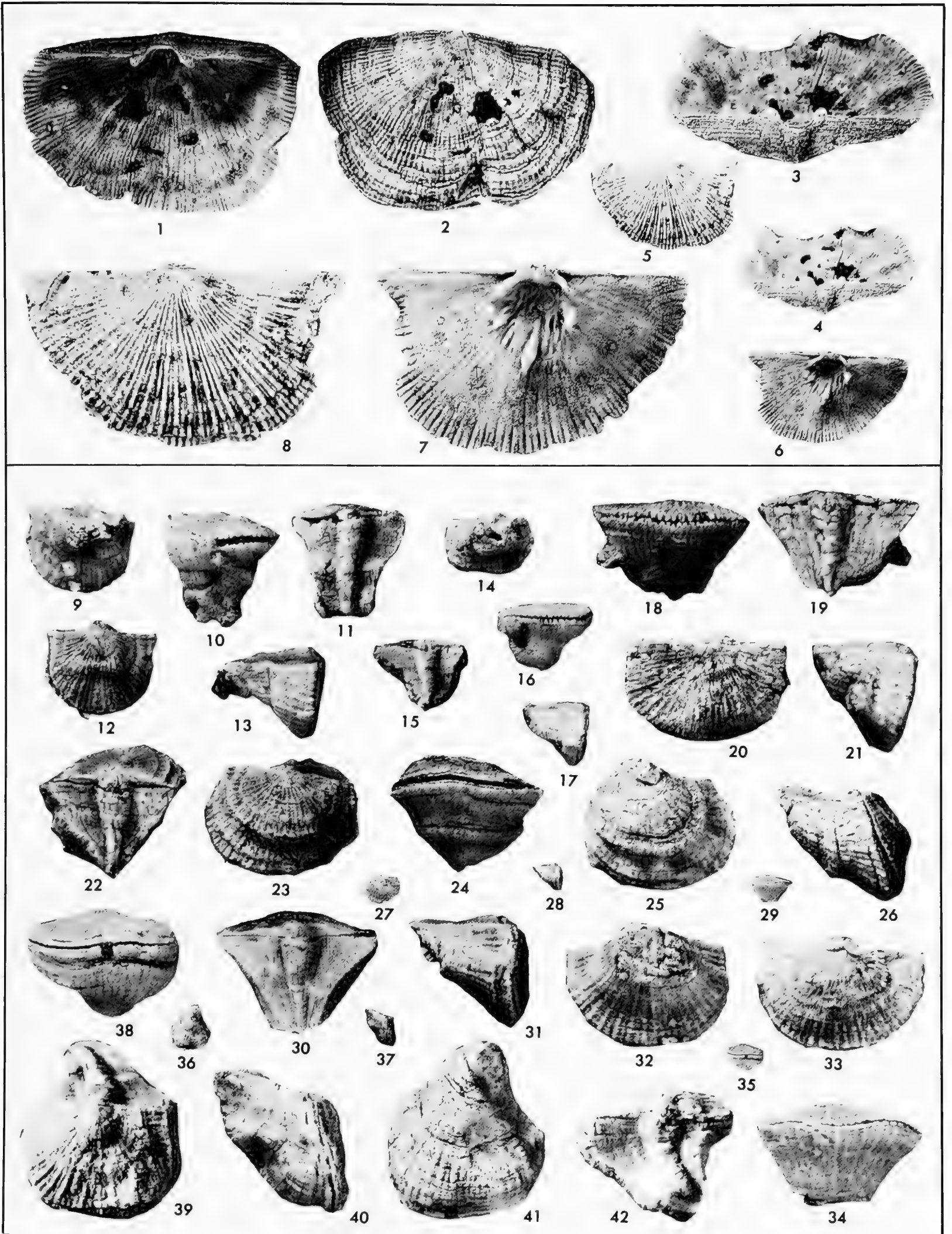
*Goniarina*

*Goniarina diabloensis*, new species: 1–3, Interior, exterior, and posterior of the pedicle valve,  $\times 1.5$ , paratype USNM 150390a; 4, posterior of same,  $\times 1$ ; 5, 6, exterior and interior of the brachial valve,  $\times 1$ , holotype USNM 150390b; 7, 8, interior and exterior of the holotype, showing cardinalia and median ridge,  $\times 2$  [Bone Spring Formation (lower) locality USNM 728f].

*Goniarina futilis*, new species: 9–13, Ventral, anterior, posterior, dorsal, and side views of a small individual,  $\times 4$ , paratype USNM 150393f; 14–17, ventral, posterior, anterior, and side views of another but still smaller specimen,  $\times 4$ , paratype USNM 150393c; 18–21, anterior, posterior, dorsal, and side views of an adult,  $\times 4$ , paratype USNM 150393h; 22–26, posterior, dorsal, anterior, ventral, and side views of a large adult,  $\times 4$ , paratype USNM 150393; 27–29, ventral, side, and anterior views,  $\times 1$ , paratype USNM 150393i; 30–34, posterior, side, ventral, dorsal, and anterior views of the same specimen,  $\times 4$ ; 35–37, anterior, ventral, and side views of a large specimen,  $\times 14$ , holotype USNM 150393j; 38–42, anterior, dorsal, side, ventral, and posterior views of the holotype,  $\times 4$  [Cathedral Mountain, locality USNM 702].



PLATE 39.—*Goniarrina*.



## PLATE 40

*Streptorhynchus* and *Goniarina*

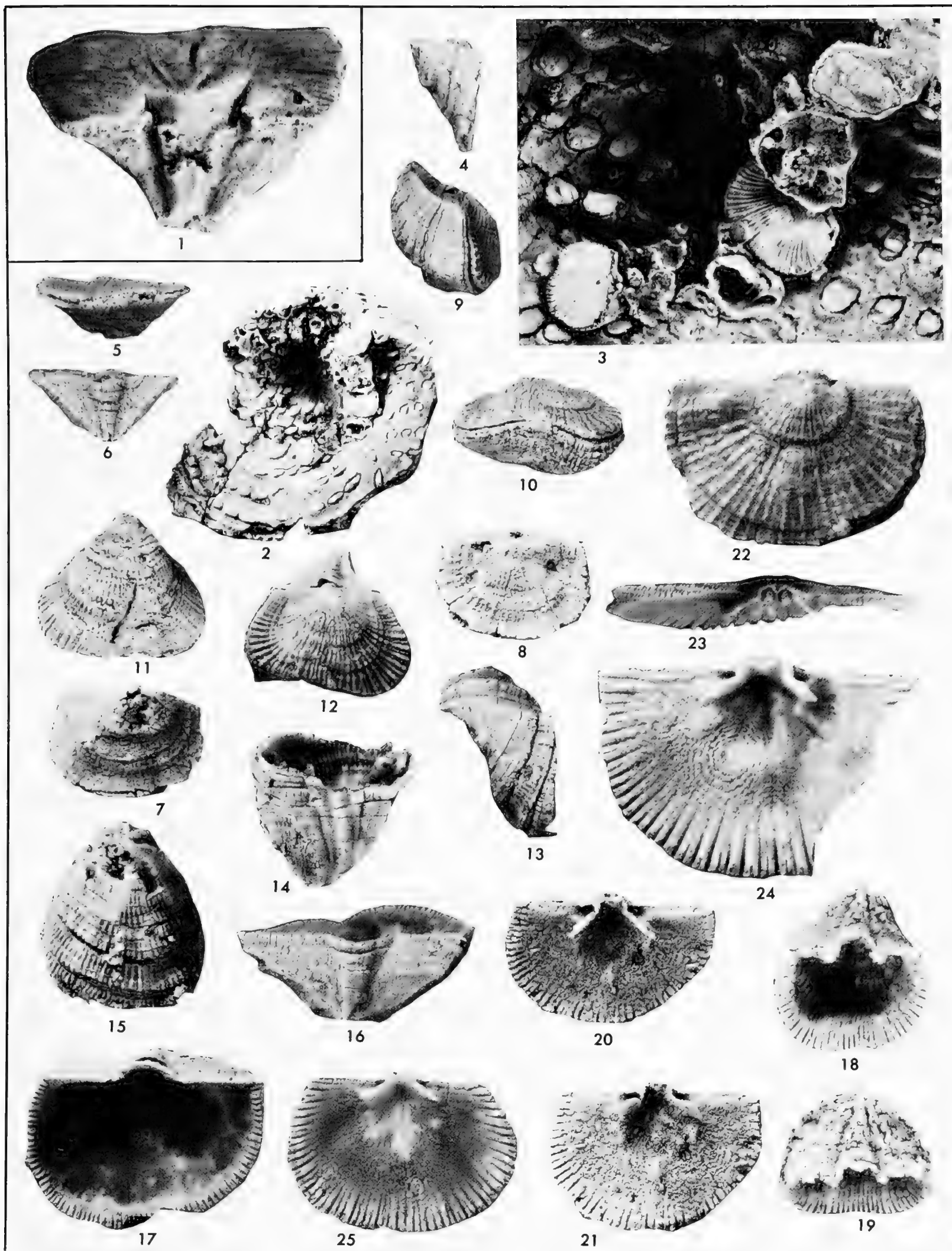
*Streptorhynchus pelargonatum* (Schlotheim): 1, Posterior view of an internal mold of a complete specimen, showing the slots produced by the supporting plates (erismata) of the cardinal process,  $\times 4$ , figured specimen YPM 27901 [Zechstein (middle), Pösneck, Thuringia, Germany].

*Goniarina striata*, new species: 2, Fragmentary specimen of *Coscinophora* with attached *G. striata*,  $\times 1$ , paratype USNM 150413; 3, the same specimen enlarged,  $\times 3$  [Road Canyon Formation, locality USNM 710u].

4–8, Side, anterior, posterior, ventral, and dorsal views of a young adult,  $\times 4$ , holotype USNM 153550a; 16, 17, posterior and interior of a large pedicle valve,  $\times 3$ , paratype USNM 150417b; 25, interior of another dorsal valve,  $\times 4$ , paratype USNM 150417c [Road Canyon Formation, locality USNM 721j].

9–12, Side, anterior, ventral, and dorsal views of a complete specimen,  $\times 3$ , paratype USNM 153551a; 13–15, side, posterior, and ventral views of a large pedicle valve with twisted beak,  $\times 3$ , paratype USNM 153551b; 22, exterior of a brachial valve,  $\times 6$ , paratype USNM 153551c; 23, 24, posterior and interior of another brachial valve, showing cardinalia,  $\times 6$ , paratype USNM 153551d [Road Canyon Formation, locality USNM 721z].

18, 19, Posterior and interior views of a thickened pedicle valve,  $\times 3$ , paratype USNM 150415c; 20, 21, tilted and interior views of a brachial valve, showing cardinalia,  $\times 4$ , paratype USNM 150415e [Road Canyon Formation, locality USNM 702d].

PLATE 40.—*Streptorhynchus* and *Goniarina*.

## PLATE 41

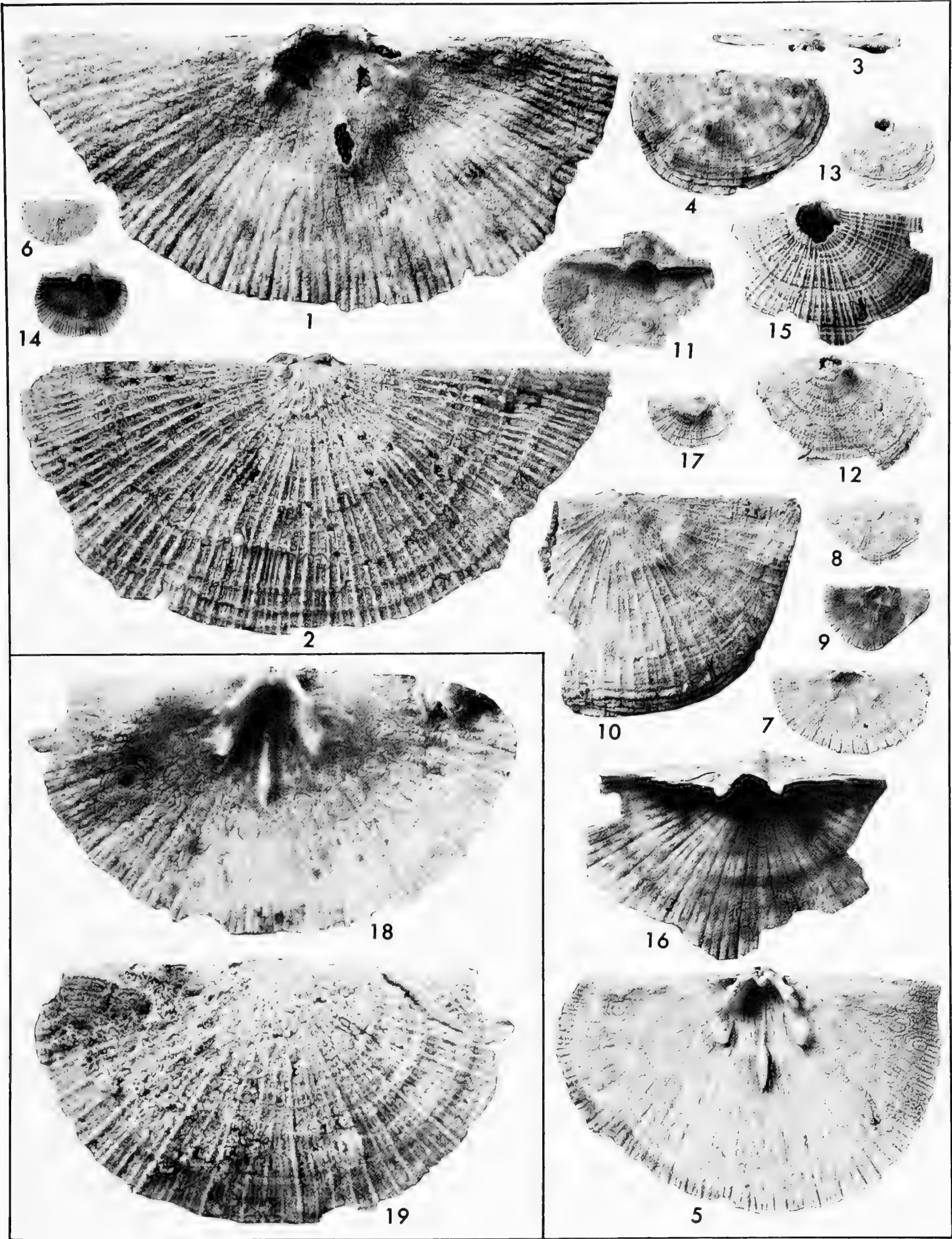
*Goniarina*

*Goniarina* species 5: 1, 2, Interior and exterior of an almost fully grown brachial valve,  $\times 3$ , figured specimen USNM 152562a; 3, 4, posterior and exterior of another nearly adult brachial valve,  $\times 1$ , figured specimen USNM 152562b; 5, interior of the same specimen, showing median ridge and cardinalia,  $\times 2$ ; 6, another immature brachial valve,  $\times 1$ , figured specimen USNM 152562e; 7, the same enlarged,  $\times 2$ ; 8, 9, exterior and interior of a small brachial valve,  $\times 1$ , figured specimen USNM 152562f; 10, exterior of an imperfect but large brachial valve,  $\times 2$ , figured specimen USNM 152562c; 11, 12, interior and exterior of a small pedicle valve,  $\times 1$ , figured specimen USNM 152562g; 13, 14, exterior and interior of another, smaller pedicle valve,  $\times 1$ , figured specimen USNM 152562h; 15, exterior of a pedicle valve,  $\times 1.5$ ; figured specimen USNM 152652i; 16, interior of the preceding, showing interarea,  $\times 2$ ; 17, exterior of an immature pedicle valve,  $\times 1$ , figured specimen USNM 152562d [Cathedral Mountain Formation (lower), locality USNM 721u].

*Goniarina* species 1: 18, 19, Interior and exterior of a medium-sized brachial valve,  $\times 3$ , figured specimen USNM 150420 [Cathedral Mountain Formation (base), locality USNM 708u].



PLATE 41.—*Goniarrina*.





## PLATE 42

*Goniarina*, *Strigirhynchia*, and *Dyoros* (*Dyoros*)

*Goniarina appeli*, new species: 1–5, Ventral, anterior, side, posterior, and dorsal views of a complete specimen,  $\times 3$ , holotype USNM 150395 [Hess Formation (Taylor Ranch Member), locality 702d].

*Goniarina* species 7: 6, 7, Interior and exterior of a brachial valve,  $\times 3$ , figured specimen USNM 152564a; 8, posterior of the same,  $\times 4$  [Cathedral Mountain, locality USNM 726x].

*Goniarina* species 3: 9–11, Interior, posterior, and exterior views of a small pedicle valve,  $\times 1$ , figured specimen USNM 153513a; 12–14, exterior, interior and posterior views of another, larger pedicle valve,  $\times 1$ , figured specimen USNM 153513b [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 722–1].

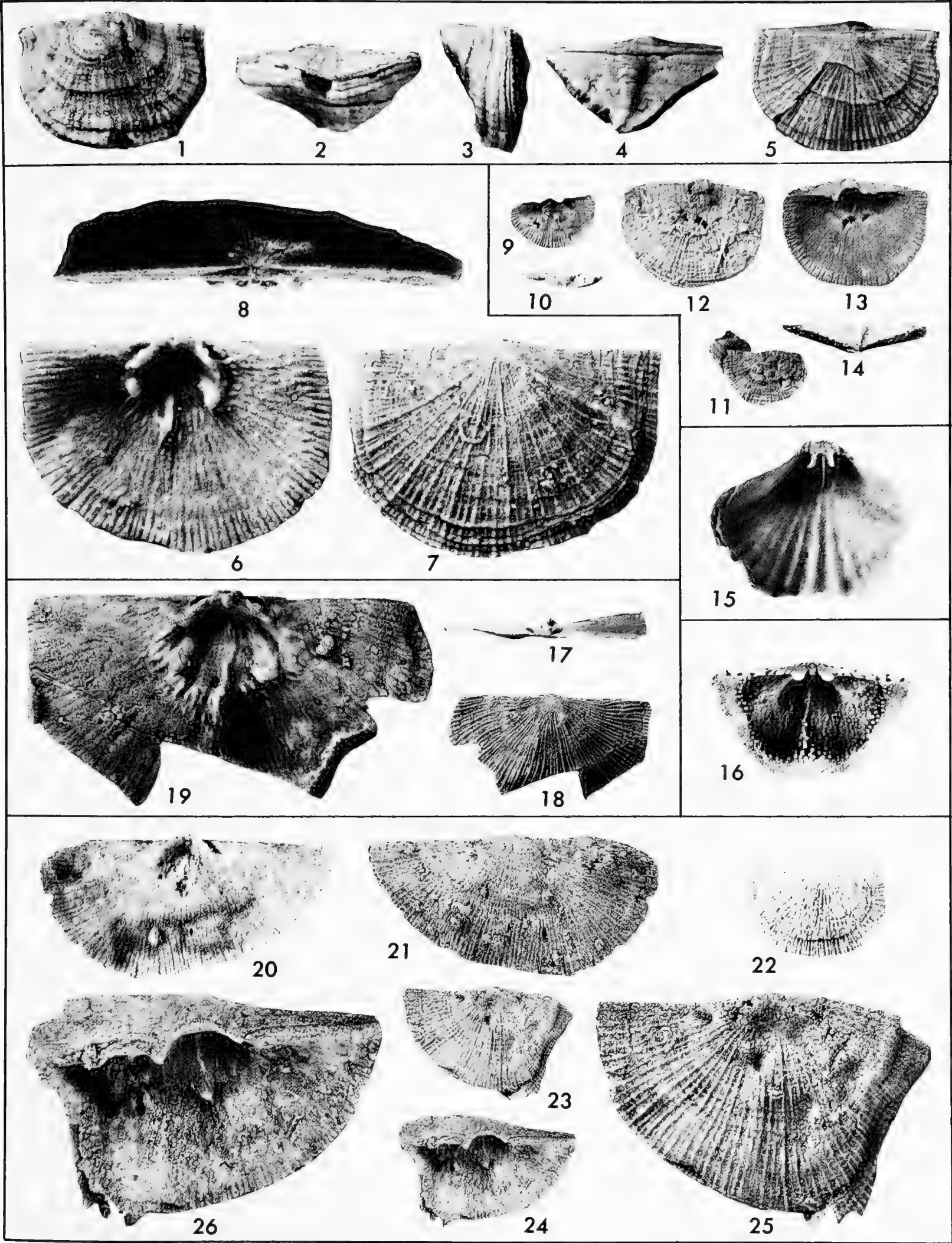
*Strigirhynchia indentata* (Shumard): 15, Interior of a brachial valve showing cardinalia and median septum,  $\times 3$ , hypotype USNM 155108 [Bell Canyon Formation (Lamar Member), locality USNM 728p].

*Dyoros* (*Dyoros*) *vulgaris*, new species: 16, Interior of the pedicle valve, showing spiny septum and endospines (taleolae),  $\times 2$ , paratype USNM 153750g [Road Canyon Formation, locality USNM 732j] (for additional views, see Plate 502: figures 46–62).

*Goniarina* species 3: 17–19, Posterior and exterior of a brachial valve,  $\times 1$ , figured specimen USNM 150423a; 19, interior of the same brachial valve, showing characteristic muscle scars and cardinalia,  $\times 2$  [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 722–1].

*Goniarina magniextensa*, new species: 20, 21, Interior and exterior of the brachial valve,  $\times 1$ , holotype USNM 150402b; 22, exterior of another less extended, brachial valve,  $\times 1$ , paratype USNM 150402g; 23, 24, exterior and interior of the pedicle valve,  $\times 1$ , paratype USNM 150402a; 25, 26, exterior and interior of the same specimen, showing incipient myophragm  $\times 2$  [Skinner Ranch Formation (base=Decie Ranch Member), locality USNM 720e].

PLATE 42.—*Goniarina*, *Strigirhynchia*, and *Dyoros* (*Dyoros*).



## PLATE 43

*Hypopsia, Derbyoides, and Goniarina*

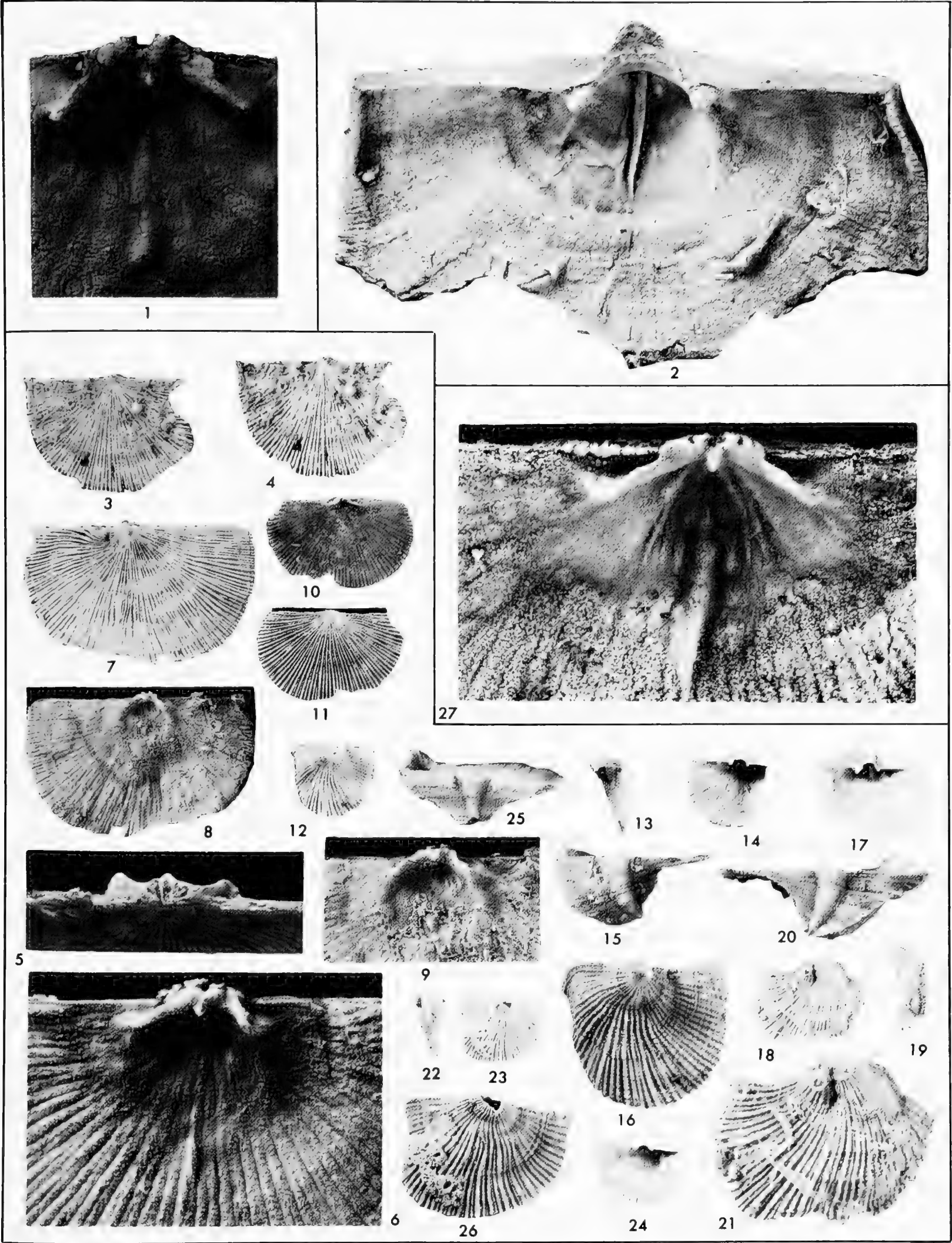
*Hypopsia versuta*, new species: 1, Cardinalia of the brachial valve,  $\times 6$ , paratype USNM 152587k [Neal Ranch Formation (bed 2 of P. B. King), locality USNM 701].

*Derbyoides nebrascensis* Dunbar and Condra: 2, Interior of the pedicle valve, showing the secondary median ridge simulating the septum of *Derbyia*,  $\times 2$ , hypotype USNM 150427d [shale just below the Cass Limestone, locality USNM 519].

*Goniarina* species 6: 3, 4, Exterior views of the brachial valve,  $\times 1$ , figured specimen USNM 153541a; 5, 6, posterior and interior of the same specimen, showing cardinalia,  $\times 4$ ; 7, 8, exterior and interior of a larger brachial valve,  $\times 1$ , figured specimen USNM 153541b; 9, cardinalia of the preceding,  $\times 4$ ; 10, 11, interior and exterior of a small brachial valve,  $\times 1$ , figured specimen 153541c; 12-14, ventral, side, and interior views of a small pedicle valve with twisted beak,  $\times 1$ , figured specimen USNM 153541d; 15, 16, posterior and exterior of the preceding specimen enlarged,  $\times 2$ ; 17-19, interior, exterior, and side views of another pedicle valve,  $\times 1$ , figured specimen USNM 153541e; 20, 21, posterior and exterior views of the same specimen,  $\times 2$ ; 22-24, side, exterior, and interior of another pedicle valve,  $\times 1$ , figured specimen USNM 153541f; 25, 26, posterior and exterior of the same specimen,  $\times 2$  [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].

*Goniarina diabloensis*, new species: 27, Interior of the brachial valve showing the cardinalia,  $\times 6$ , paratype USNM 150390k [Bone Spring Formation (lower), locality USNM 728f].

PLATE 43.—*Hypopsia*, *Derbyoides*, and *Goniarrina*.



## PLATE 44

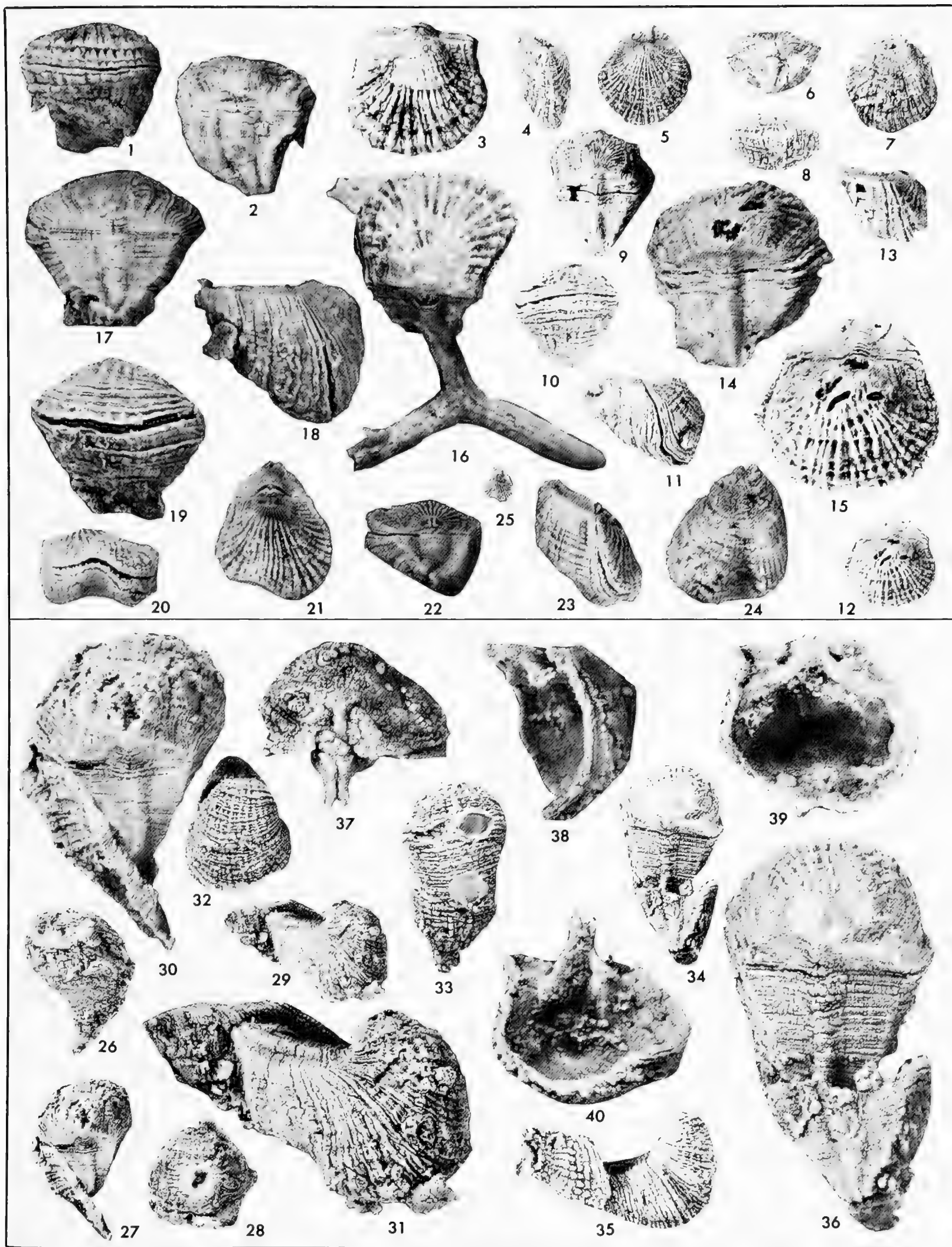
*Diplanus*

*Diplanus catatonus*, new species: 1–3, Anterior, posterior, and dorsal views of a small specimen,  $\times 3$ , paratype USNM 150432i; 4–8, side, dorsal, posterior, ventral, and anterior views of an adult,  $\times 1$ , paratype USNM 153496k; 9–11, posterior, anterior, and side views of a large specimen,  $\times 1$ , paratype USNM 153496–1; 16, small specimen attached to a bryozoan,  $\times 4$ , paratype USNM 153496m; 17–19, posterior, side, and anterior views of a large specimen,  $\times 2$ , paratype USNM 153496n; 20–24, anterior, dorsal, posterior, side and ventral views of a small specimen distorted by attachment,  $\times 4$ , paratype USNM 150432k [Neal Ranch Formation, locality USNM 701d].

12, 13, Dorsal and side views of specimen bored by barnacles,  $\times 1$ , paratype USNM 150433b; 14, 15, posterior and dorsal views,  $\times 2$ , of the same specimen; 25, dorsal view of same [Neal Ranch Formation, locality USNM 701h].

*Diplanus apochordus*, new species: 26–29, anterior, posterior, dorsal, and side views of a small specimen,  $\times 1$ , paratype USNM 150440a; 30, 31, posterior and side views of the same specimen, showing interareas,  $\times 2$ ; 32–35, dorsal, anterior, posterior, and side views of a large specimen,  $\times 1$ , holotype USNM 150440b; 36, posterior of the holotype,  $\times 2$ ; 37–40, posterior, side, interior, and anteriorly tilted views of a brachial valve,  $\times 3$ , paratype USNM 150440c [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].



PLATE 44.—*Diplanus*.

## PLATE 45

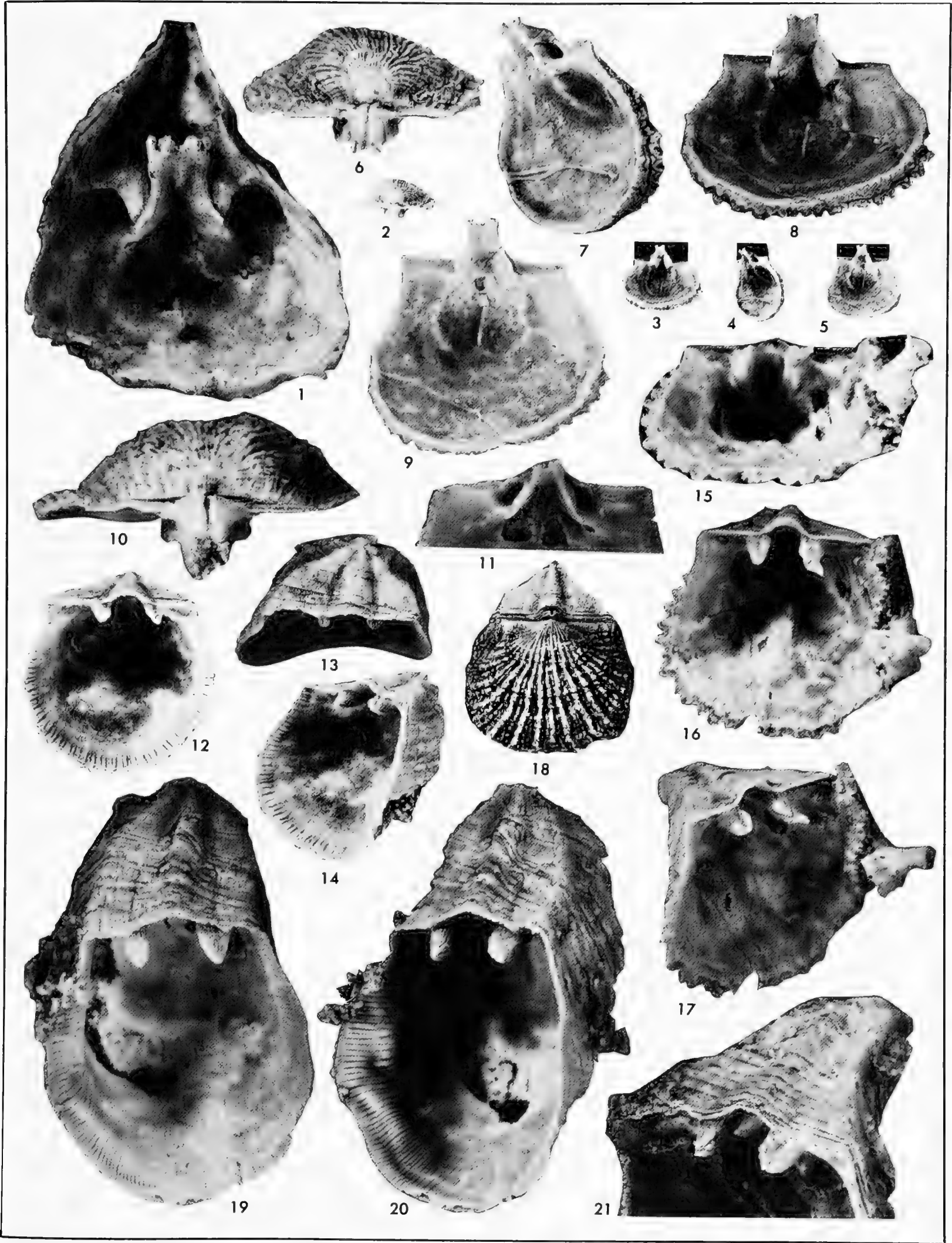
*Diplanus*

*Diplanus catatonus*, new species: 1, Interior of the dorsal valve with part of pedicle valve attached, showing teeth and thick, long cardinal process,  $\times 4$ , paratype USNM 153496o; 10, posterior of the brachial valve, showing the large cardinal process,  $\times 4$ , paratype USNM 153496p; 11, interior of another brachial valve, showing the large sockets,  $\times 4$ , paratype USNM 153496q; 12–14, interior, posterior, and laterally tilted views of the pedicle valve, showing the large teeth,  $\times 4$ , paratype USNM 153496r; 15–17, interior of the pedicle valve in anteriorly tilted, direct, and laterally tilted views, showing the huge teeth,  $\times 4$ , paratype USNM 153496s; 19–21, interior, lateral, and posterolateral views of another large pedicle valve,  $\times 4$ , paratype USNM 153496t [Neal Ranch Formation, locality USNM 701d].

2–5, Posterior, anteriorly tilted, laterally tilted, and interior views of a brachial valve,  $\times 1$ , paratype USNM 150434a; 6–9, posterior, laterally tilted, anteriorly tilted, and interior views of the same specimen, showing deep sockets and cardinal process,  $\times 3$  [Neal Ranch Formation, locality USNM 701k].

18, Exterior of a complete specimen,  $\times 2$ , paratype USNM 150433c [Neal Ranch Formation, locality USNM 701h].

PLATE 45.—*Diplanus*.



## PLATE 46

*Diplanus*

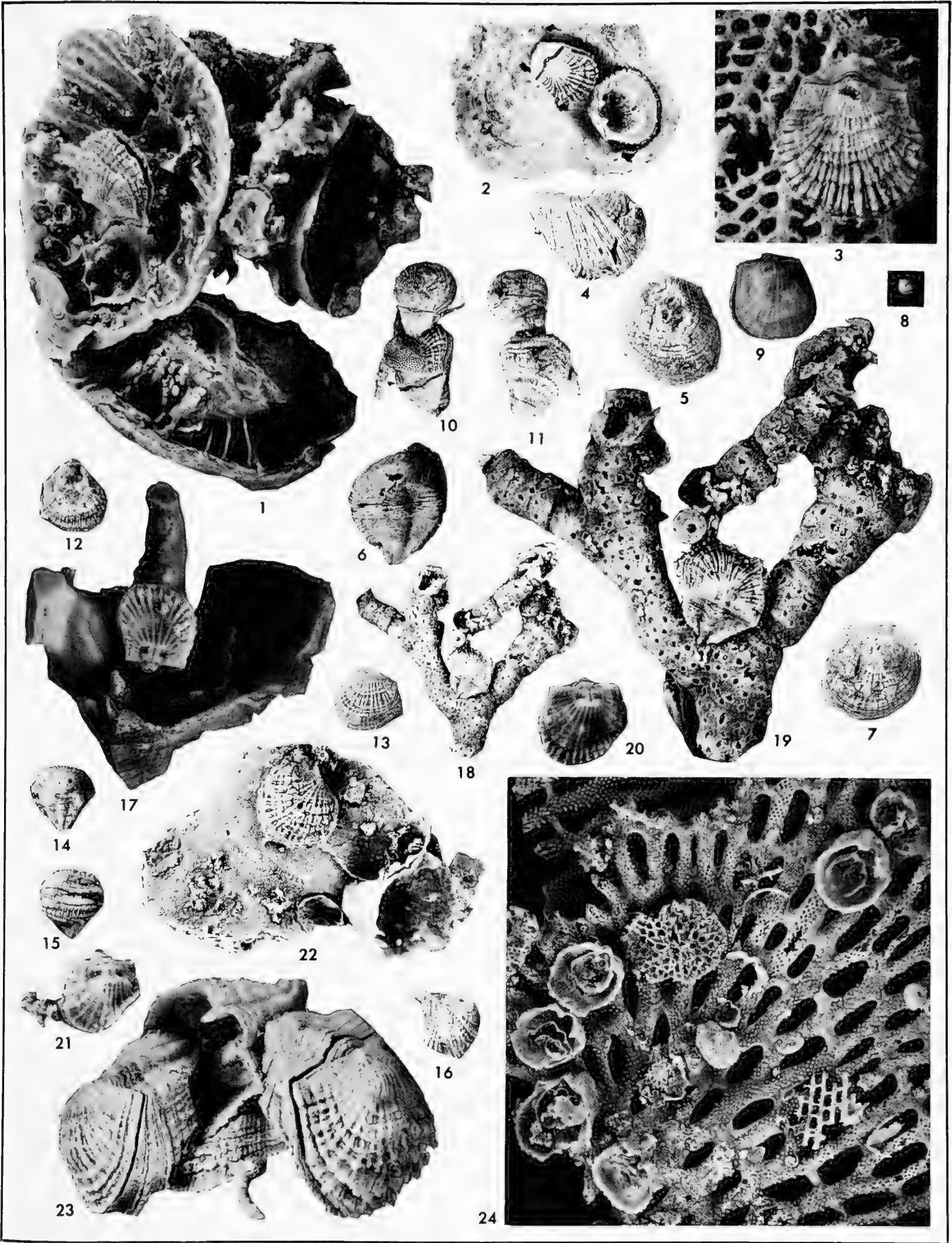
*Diplanus catatonus*, new species: 1, Several specimens attached to *Eolyttonia* and associated with *Teguliferina*,  $\times 2$ , paratype USNM 150431a [Neal Ranch Formation, locality USNM 701c].

2, Two individuals attached to a brachial valve of *Limbella*,  $\times 1$ , paratype USNM 153496a; 3, another individual attached to the apertural side of a fenestellid colony,  $\times 3$ , paratype USNM 153496b; 4-7, side, ventral, posterior, and dorsal views,  $\times 1$ , holotype USNM 150432a; 8, 9, dorsal view of an immature specimen  $\times 1$ ,  $\times 5$ , paratype USNM 153496c; 10, 11, views of two attached specimens,  $\times 1$ , paratype USNM 153496d; 12-16, ventral, dorsal, posterior, anterior, and side views of an average specimen,  $\times 1$ , paratype USNM 150432e; 17, immature specimen attached to a bryozoan stem,  $\times 6$ , paratype USNM 153496e; 18, 19, small specimen attached to a sponge,  $\times 1$ ,  $\times 2$ , paratype USNM 153496f; 20, 21, dorsal view of two immature specimens,  $\times 5$ , paratypes USNM 153496g, h; 23, cluster of specimens showing mode of attachment,  $\times 3$ , paratype USNM 153496i; 24, numerous small individuals attached to the cellular face of a fenestellid colony,  $\times 3$ , paratype USNM 153496j [Neal Ranch Formation, locality USNM 701d].

22 Bryozoan frond with attached *Diplanus* and *Geyerella*  $\times 1$ , paratype USNM 150433a [Neal Ranch Formation, locality USNM 701h].



PLATE 46.—*Diplanus*.





## PLATE 47

*Diplanus*

*Diplanus lamellatus* (R. E. King): 1, 2, Specimen attached to the pedicle valve of *Institella*,  $\times 1$ , hypotype USNM 150462a; 13–17, dorsal, side, anterior, ventral, and posterior views of a specimen with twisted beak,  $\times 2$ , hypotype USNM 150462b [Cathedral Mountain Formation (Wedin Member), locality USNM 714w].

3, Dorsal view of rounded specimen attached to *Eolyttonia*,  $\times 1$ , hypotype USNM 150446c; 24–27, anterior, posterior, ventral, and side views of a complete specimen,  $\times 2$ , hypotype USNM 150446d [Hess Formation (Taylor Ranch Member), locality USNM 702d].

4–6, Three views of a small specimen attached to a bryozoan colony,  $\times 3$ , hypotype USNM 150470a [Bone Spring Formation (base), locality USNM 728f].

7, Dorsal view of a small attached specimen,  $\times 3$ , hypotype USNM 153505 [Cathedral Mountain Formation (Wedin Member), locality USNM 700–1].

8–10, Anterior, posterior, and side views of an elongated specimen,  $\times 2$ , hypotype USNM 150454a [Skinner Ranch Formation (=Taylor Ranch Member), locality USNM 705r].

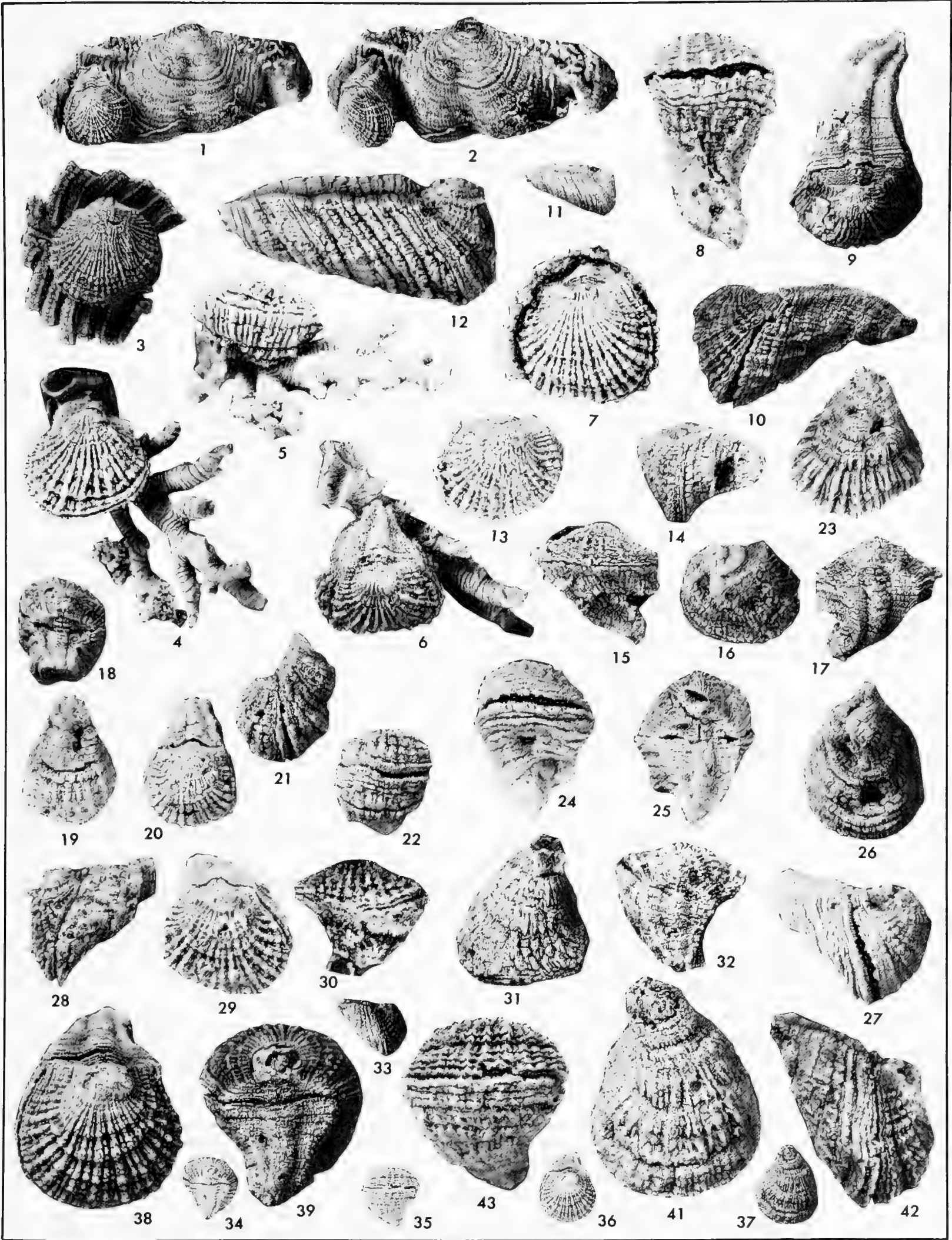
11, 12, Side view of another greatly elongated specimen,  $\times 1$ ,  $\times 2$ , hypotype USNM 150541a [Cathedral Mountain Formation (base), locality USNM 703bs].

18–22, Posterior, ventral, dorsal, side, and anterior views of a small stout individual,  $\times 2$ , hypotype USNM 150444a; 23, ventral view of a complete specimen,  $\times 2$ , hypotype USNM 153502b [Cathedral Mountain Formation (lower), locality AMNH 500=USNM 702] (for additional views, see Plate 48: figures 9–12).

28–32, Side, dorsal, anterior, ventral, and posterior views,  $\times 2$ , hypotype USNM 153506 [Bone Spring Formation, locality AMNH 660].

33–37, Side, posterior, anterior, dorsal, and ventral views of a complete specimen,  $\times 1$ , hypotype USNM 153507; 38–42, dorsal, posterior, anterior, ventral, and side views of the same specimen,  $\times 3$  [Bone Spring Formation (middle), locality AMNH 658].

PLATE 47.—*Diplanus*.



## PLATE 48

*Diplanus*

*Diplanus lamellatus* (R. E. King): 1-3, Interior, posterior, and tilted views of the pedicle valve,  $\times 2$ , hypotype USNM 153501 [Bone Spring Formation (base), locality AMNH 625].

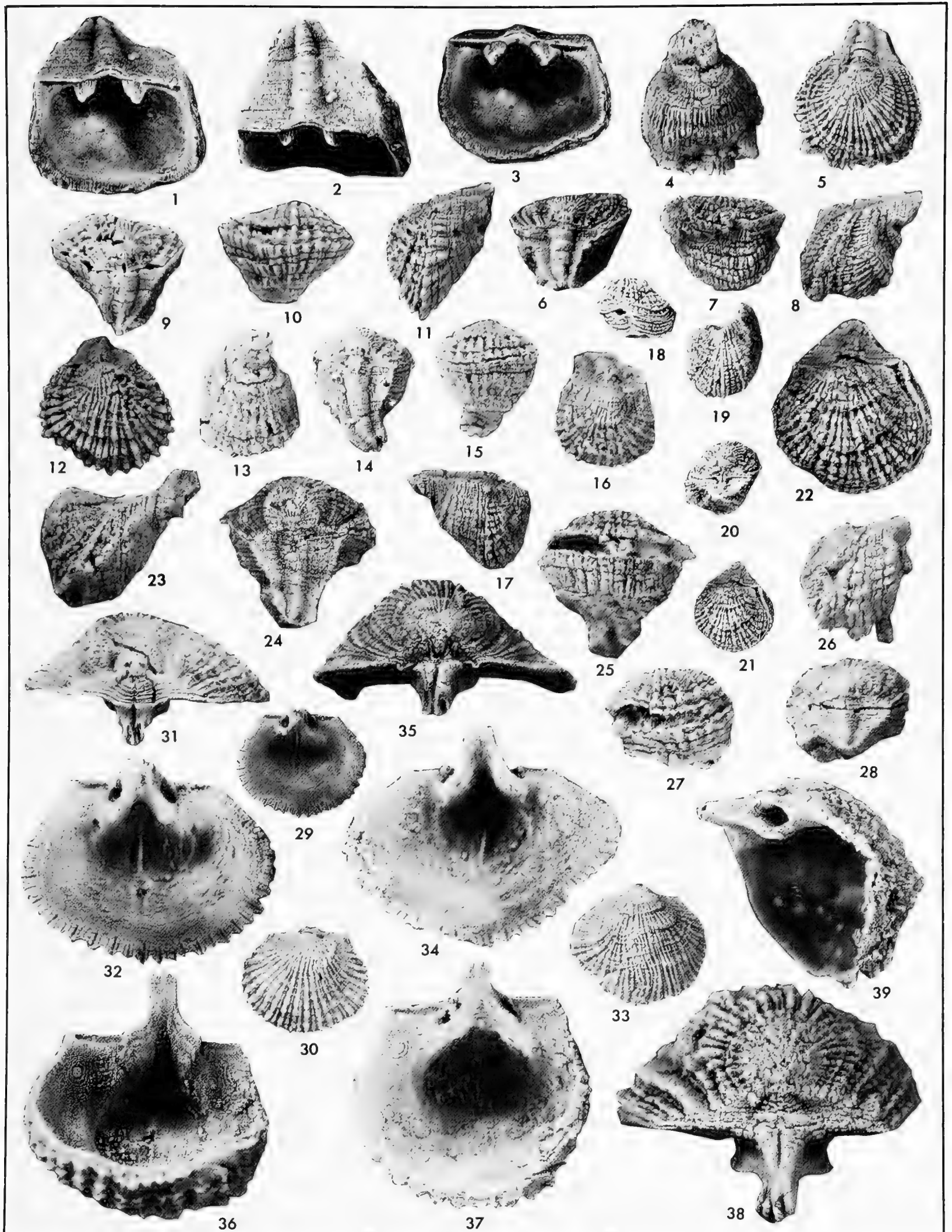
4-8, Ventral, dorsal, posterior, anterior, and side views of a complete specimen,  $\times 2$ , hypotype USNM 153502a; 9-12, posterior, anterior, side, and dorsal views of another complete specimen,  $\times 2$ , hypotype USNM 153502b [Cathedral Mountain Formation, locality AMNH 500=USNM 702] (for additional view, see Plate 47; figure 23).

13-17, Ventral, posterior, anterior, dorsal, and side views,  $\times 2$ , hypotype USNM 153503a; 18-21, anterior, side, posterior, and dorsal views of a rotund individual,  $\times 1$ , hypotype USNM 153503b; 22, dorsal view of the preceding,  $\times 2$  [Skinner Ranch Formation, (Decie Ranch Member), locality USNM 707a].

23-25, Side, posterior, and anterior views,  $\times 2$ , hypotype USNM 150446a; 26-28, side, anterior, and posterior views of another specimen,  $\times 2$ , hypotype USNM 150446b [Hess Formation (Taylor Ranch Member), locality USNM 702d].

29, 30, Interior and exterior of a brachial valve,  $\times 2$ , hypotype USNM 153498a; 31, 32, posterior and interior of the same specimen, showing cardinal process and sockets,  $\times 4$ ; 33, exterior of another brachial valve with finer costae,  $\times 2$ , hypotype USNM 153498b; 34, 35, interior tilted posteriorly and posterior, showing cardinalia and small median ridge,  $\times 4$  [Cathedral Mountain Formation, (lower), locality USNM 721u].

36-39, Brachial valve tilted posteriorly, in full view, posterior view, and tilted laterally to show cardinalia and long cardinal process,  $\times 3$ , hypotype USNM 153504 [Skinner Ranch Formation (lower=Decie Ranch), locality USNM 705a].

PLATE 48.—*Diplanus*.

## PLATE 49

*Diplanus*

*Diplanus lamellatus* (R. E. King): 1-3, Posterior view,  $\times 2$ ,  $\times 1$ , and side view,  $\times 1$ , holotype YPM 11399 [Leonard=Cathedral Mountain Formation, King locality 245].

4, 5, Exterior of two brachial valves,  $\times 1$ ,  $\times 2$ , paratypes YPM 11398a, b [Hess Formation = Skinner Ranch Formation (base?), King locality 105].

*Diplanus lamellatus* (R. E. King). 6-8, Exterior, interior, and posterior views of pedicle valve,  $\times 2$ , hypotype USNM 153498f [Cathedral Mountain Formation (lower), locality USNM 721u].

9-12, Laterally tilted,  $\times 3$ , posterior,  $\times 4$ , and interior and posteriorly tilted,  $\times 3$ , views of a well-preserved brachial valve, hypotype USNM 153499a [Bone Spring Formation (lower), locality USNM 728e].

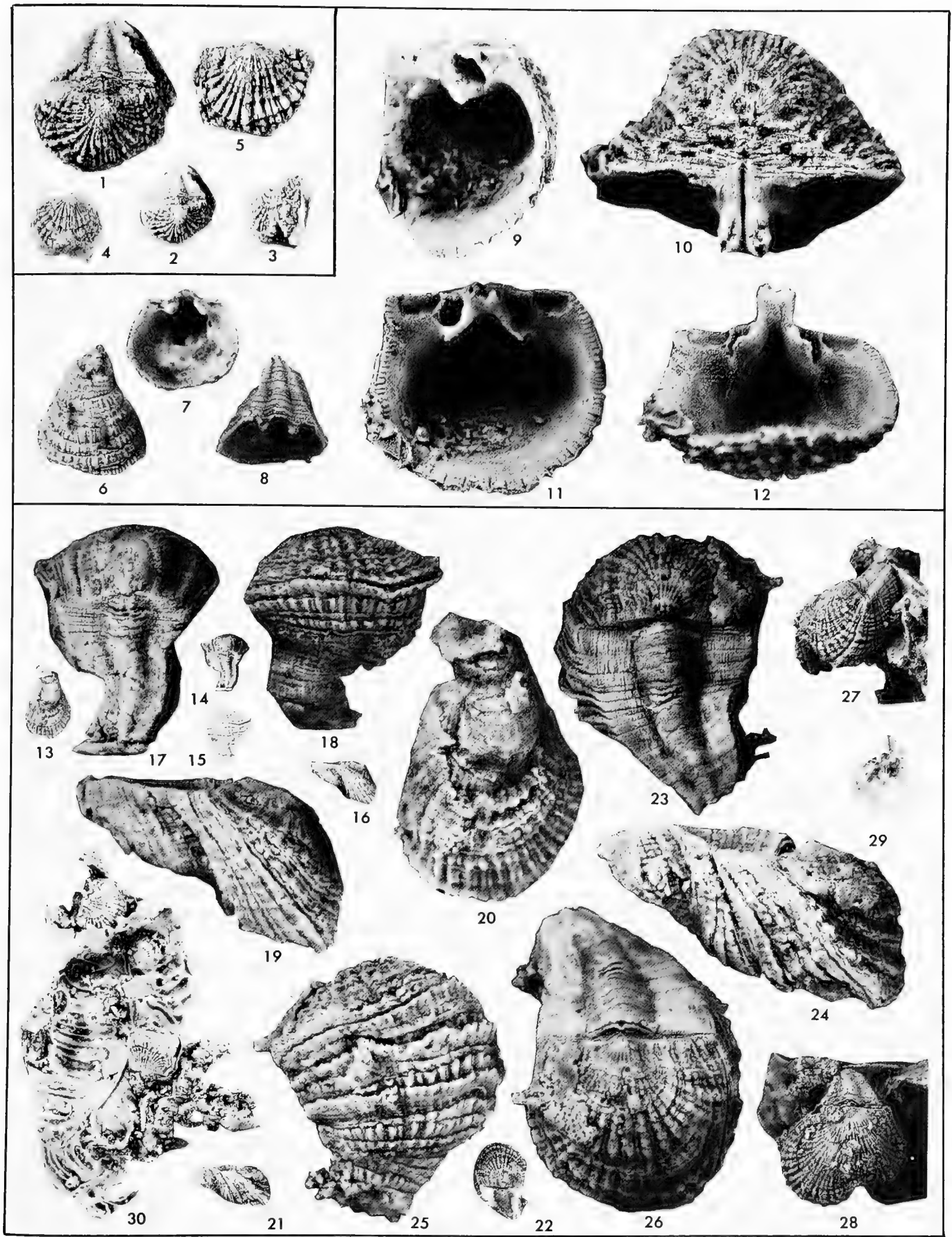
*Diplanus catatonus*, new species: 13-16, Ventral, posterior, anterior, and side views of a specimen with elongated and twisted beak,  $\times 1$ , paratype USNM 150432h; 17-20, posterior, anterior, side, and ventral views of the same specimen,  $\times 4$ ; 21, 22, side and posterior views of another complete specimen,  $\times 1$ , paratype USNM 150432g; 23-26, posterior, side, anterior, and dorsal views of the same specimen,  $\times 4$ ; 30, part of an *Eolyttonia* with adhering *Diplanus*,  $\times 1$ , paratype USNM 153496u [Neal Ranch Formation, locality USNM 701d].

27, 28, Side and dorsal views of an adherent specimen,  $\times 2$ , paratype USNM 153500 [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 701-1].

29, Interior of a pedicle valve, showing costae extending beyond shell margin,  $\times 1$ , paratype USNM 150434c [Neal Ranch Formation, locality USNM 701k].



PLATE 49.—*Diplanus*.



## PLATE 50

*Diplanus*

*Diplanus rarus*, new species: 1–5, Dorsal, side, ventral, anterior, and posterior views of a complete specimen,  $\times 2$ , paratype USNM 153497a; 6–10, posterior, dorsal, anterior, side, and ventral views of a fine ribbed specimen,  $\times 1$ , paratype, USNM 153497b; 11–14, dorsal, posterior, anterior, and side views of the same specimen,  $\times 2$  [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

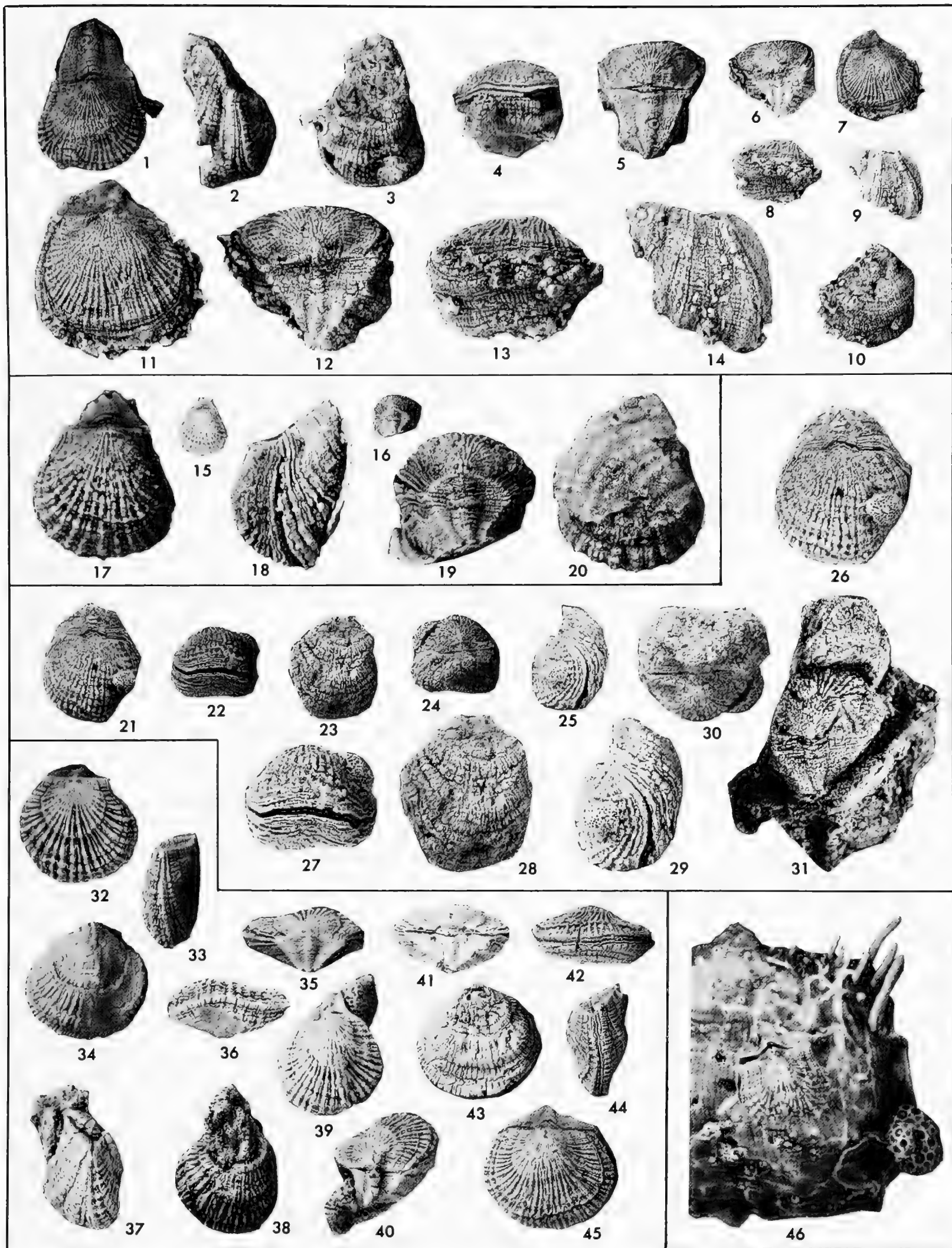
*Diplanus lamellatus* (R. E. King): 15, 16, Dorsal and posterior views,  $\times 1$ , hypotype, USNM 150459a; 17–20, dorsal, side, posterior, and ventral views of the same specimen,  $\times 3$  [Cathedral Mountain (base), locality USNM 708].

*Diplanus rarus*, new species: 21–25, Dorsal, anterior, ventral, posterior, and side views of a complete specimen,  $\times 1$ , holotype USNM 150472a; 26–30, dorsal, anterior, ventral, side, and posterior views of the holotype,  $\times 2$ ; 31, another specimen attached in living position,  $\times 1$ , paratype USNM 150472b [Skinner Ranch Formation (Decie Ranch Member), locality USNM 714p].

*Diplanus redactus*, new species: 32–36, Dorsal, side, ventral, posterior, and anterior views of a small specimen,  $\times 2$ , paratype USNM 150474a [Gaptank Formation (bed 10 of P. B. King), locality USNM 700a].

37–40, Side, ventral, dorsal, and posterior views of another small specimen,  $\times 2$ , paratype USNM 150475b; 41–45, posterior, anterior, ventral, side, and dorsal views of the holotype, USNM 150475a [Gaptank Formation (*Uddenites*-bearing Shale Member) locality USNM 701e].

*Diplanus catatonus*, new species: 46, Specimen attached to the ventral surface of a *Limbella*,  $\times 2$ , paratype USNM 150434b [Neal Ranch Formation, locality USNM 701k].

PLATE 50.—*Diplanus*.

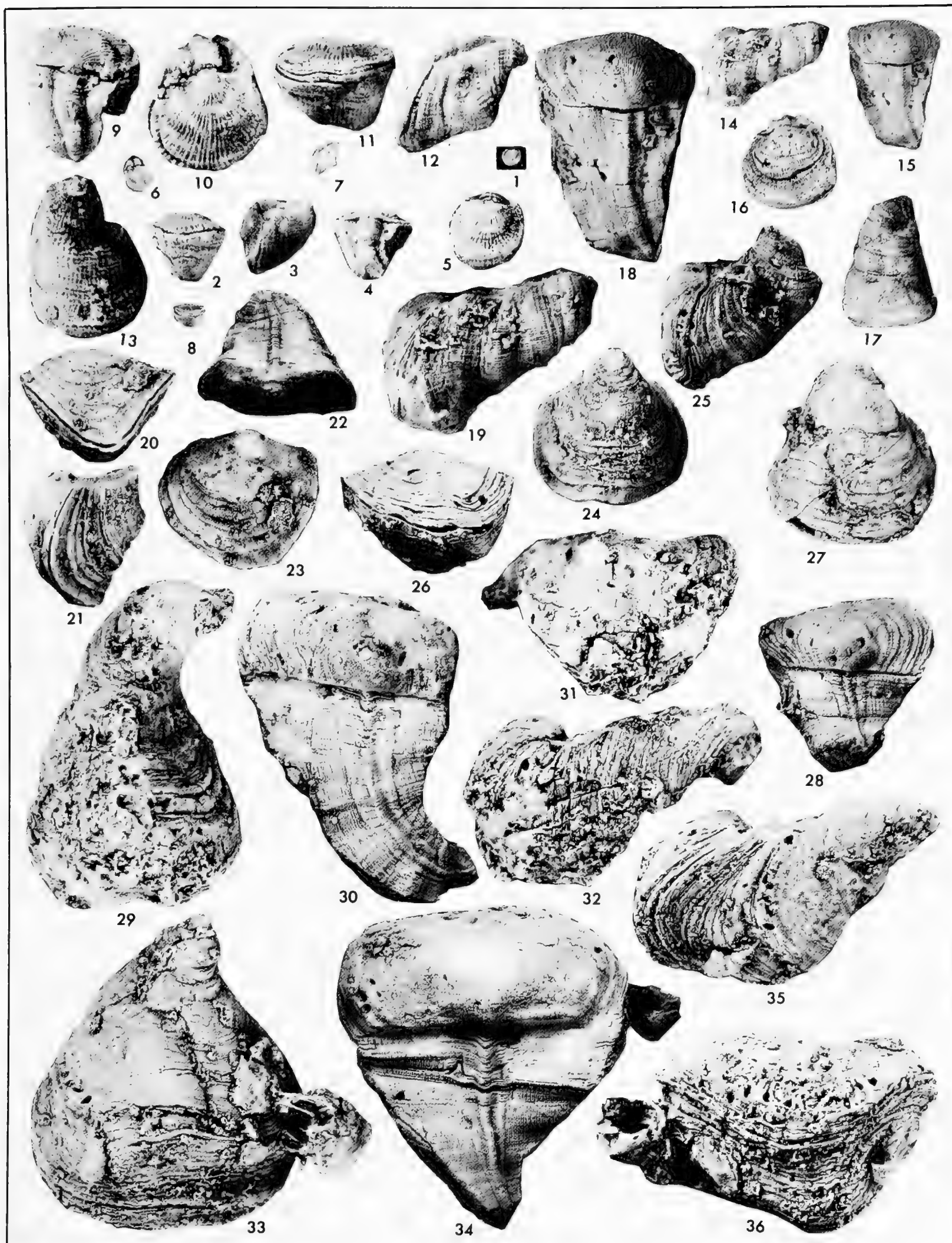
## PLATE 51

*Tropidelasma*

*Tropidelasma culmenatum* Cooper and Grant: 1, Dorsal view of an immature specimen,  $\times 1$ , paratype USNM 147829i; 2-5, anterior, side, posterior, and dorsal views of the preceding specimen,  $\times 4$ ; 6-8, dorsal, side and anterior views of another larger immature individual,  $\times 1$ , paratype USNM 147829h; 9-13, posterior, dorsal, anterior, side, and ventral views of the preceding specimen,  $\times 4$ ; 14-17, side, posterior, dorsal, and ventral views of a small adult,  $\times 1$ , paratype USNM 147829e; 18, 19, posterior and side views of the preceding specimen,  $\times 2$ ; 20-24, anterior, side, posterior, dorsal, and ventral views of a young adult,  $\times 1$ , paratype USNM 147829c; 25-28, side, anterior, ventral, and posterior views of a specimen larger than the preceding,  $\times 1$ , paratype USNM 147829k; 29-32, ventral, posterior, dorsal, and side views of a large, greatly elongated adult,  $\times 1$ , holotype USNM 147829b; 33-36, ventral, posterior, side, and anterior views of a large adult,  $\times 1$ , paratype USNM 147829a [Neal Ranch Formation, locality USNM 701h].



PLATE 51.—*Tropidelasma*.





## PLATE 52

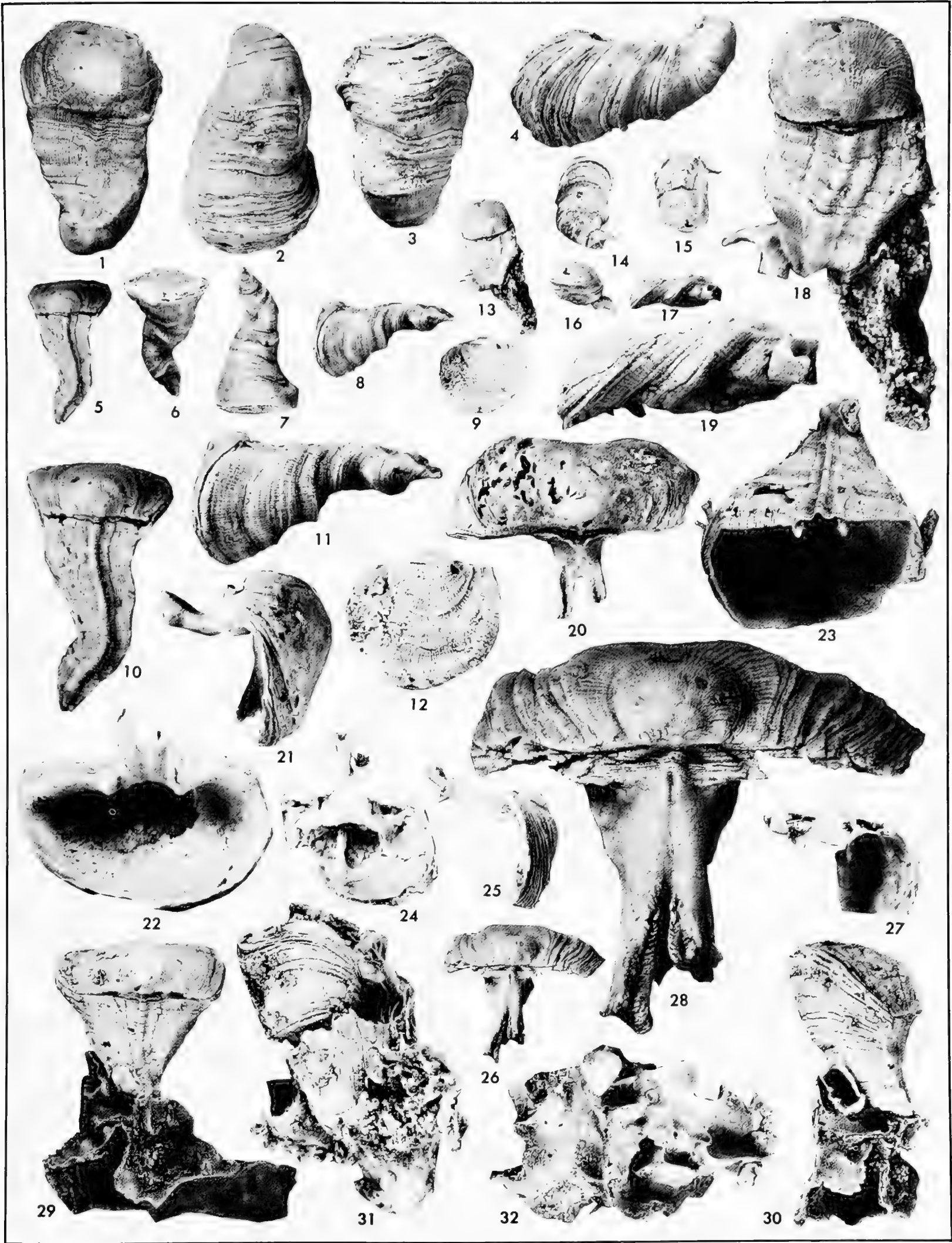
*Tropidelasma*

*Tropidelasma culmenatum* Cooper and Grant: 1-4, Posterior, ventral, anterior, and side views, of a young adult,  $\times 1$ , paratype USNM 153559a; 31, young adult attached within the pedicle valve of another specimen,  $\times 1$ , paratype USNM 153559b; 32, young specimen attached to a large bryozoan colony,  $\times 0.5$ , paratype USNM 147873 [Neal Ranch Formation, locality USNM 701k].

5-9, Posterior, anterior, ventral, side, and dorsal views of a greatly elongated young specimen,  $\times 1$ , paratype USNM 147838; 10-12, posterior, side, and dorsal views of the preceding specimen,  $\times 2$ ; 13-17, posterior, ventral, dorsal, anterior, and side views of a young specimen attached to a fragment of sponge (and free of the sponge),  $\times 1$ , paratype USNM 153560a; 18, 19, enlargement of the posterior and side views of the preceding specimen,  $\times 2$ ; 23, posterior view of a pedicle valve, showing teeth and monticulus on the pseudodeltidium,  $\times 1$ , paratype USNM 153560b; 24-27, anterior, side, posterior, and partial side views of a fragmentary brachial valve, showing one aborted prong of the cardinal process,  $\times 1$ , paratype USNM 147829-1; 28, posterior of the preceding specimen, showing also the chilidial structures,  $\times 3$  (for additional views, see Plate 53); 29, 30, small adult attached to part of a bryozoan colony,  $\times 1$ , paratype USNM 153560c [Neal Ranch Formation, locality USNM 701h].

20-22, Posterior, side, and anterior views of a brachial valve, showing the large cardinal process,  $\times 1$ , paratype USNM 147875 [Neal Ranch Formation (Gray Limestone of P. B. King), locality USNM 701].

PLATE 52.—*Tropidelasma*.



## PLATE 53

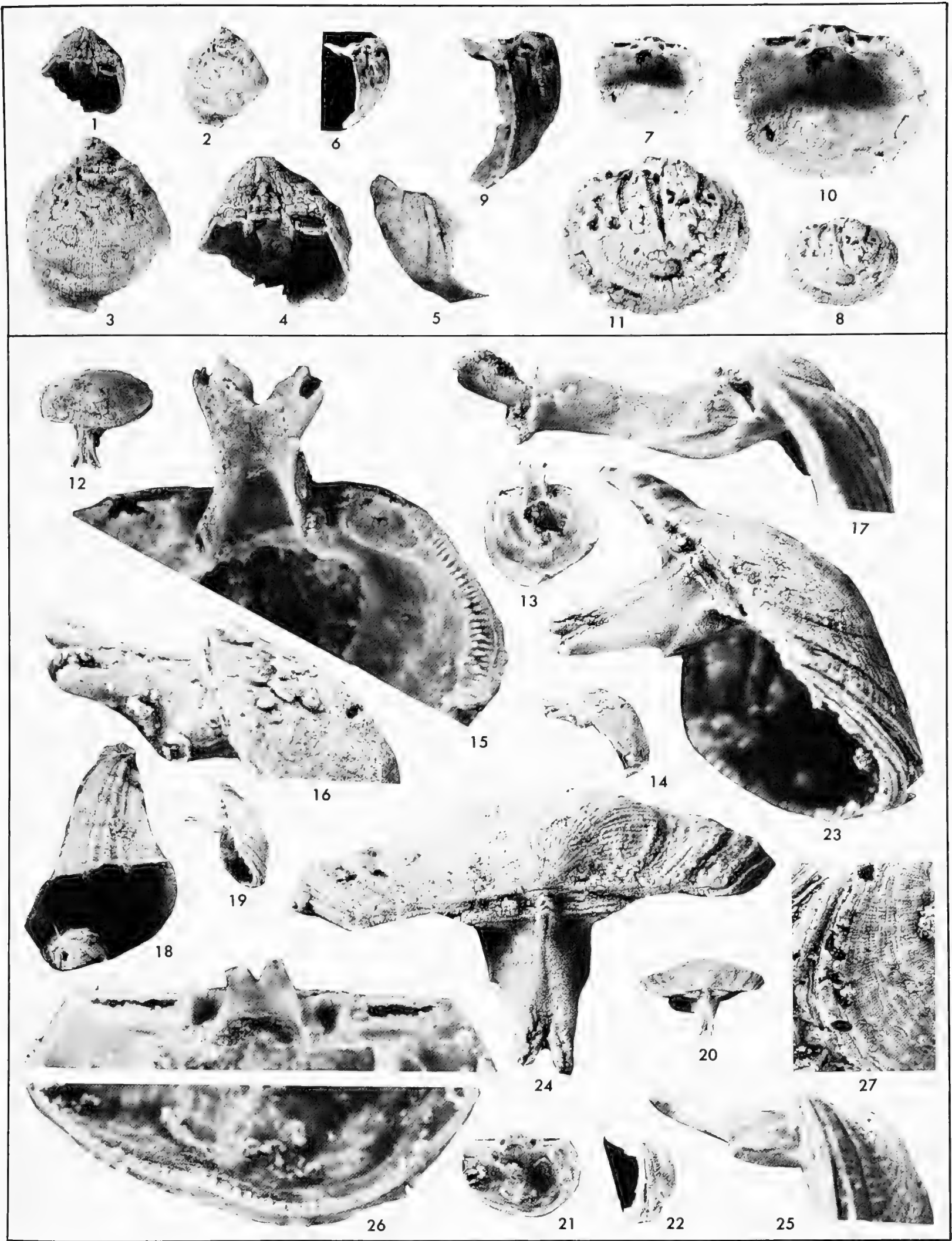
*Tropidelasma*

*Tropidelasma furcillatum*, new species; 1, 2, Dorsal and ventral views of an imperfect pedicle valve,  $\times 1$ , holotype USNM 153561a; 3-5, ventral, dorsal, and side views of the holotype,  $\times 2$ ; 6-8, side, interior, and exterior views of a brachial valve,  $\times 1$ , paratype USNM 153561b; 9-11, side, interior, and exterior views of the preceding specimen,  $\times 2$  [Cherry Canyon Formation (Getaway Member), locality USNM 732].

*Tropidelasma culmenatum* Cooper and Grant: 12-14, Posterior, interior, and partial side views of a small brachial valve,  $\times 1$ , paratype 147865a; 15, 16, anterior and partial side views of the cardinal process of the preceding specimen,  $\times 4$ ; 19-22, partial side, posterior, interior, and side views of another brachial valve,  $\times 1$ , paratype 147865b; 23-25, partial side, posterior and side views of the preceding specimen, showing the long shaft, small myophore, and the chilidial structures at the base of the cardinal process,  $\times 4$ ; 26, posterior and anterior margins of the preceding specimen, showing the beaded elevations along the inner anterior margin,  $\times 4$  [Neal Ranch Formation, locality USNM 701k].

17, Side view of the cardinal process of another specimen, showing an aborted prong,  $\times 4$  (for the posterior view of this specimen, see Plate 52: figure 28), paratype USNM 147829-1; 18, interarea of a pedicle valve with elongated beak,  $\times 1$ , paratype USNM 153560d; 27, side view, showing barnacle borings,  $\times 2$ , part of a paratype USNM 147829a [Neal Ranch Formation, locality USNM 701h].

PLATE 53.—*Tropidelasma*.



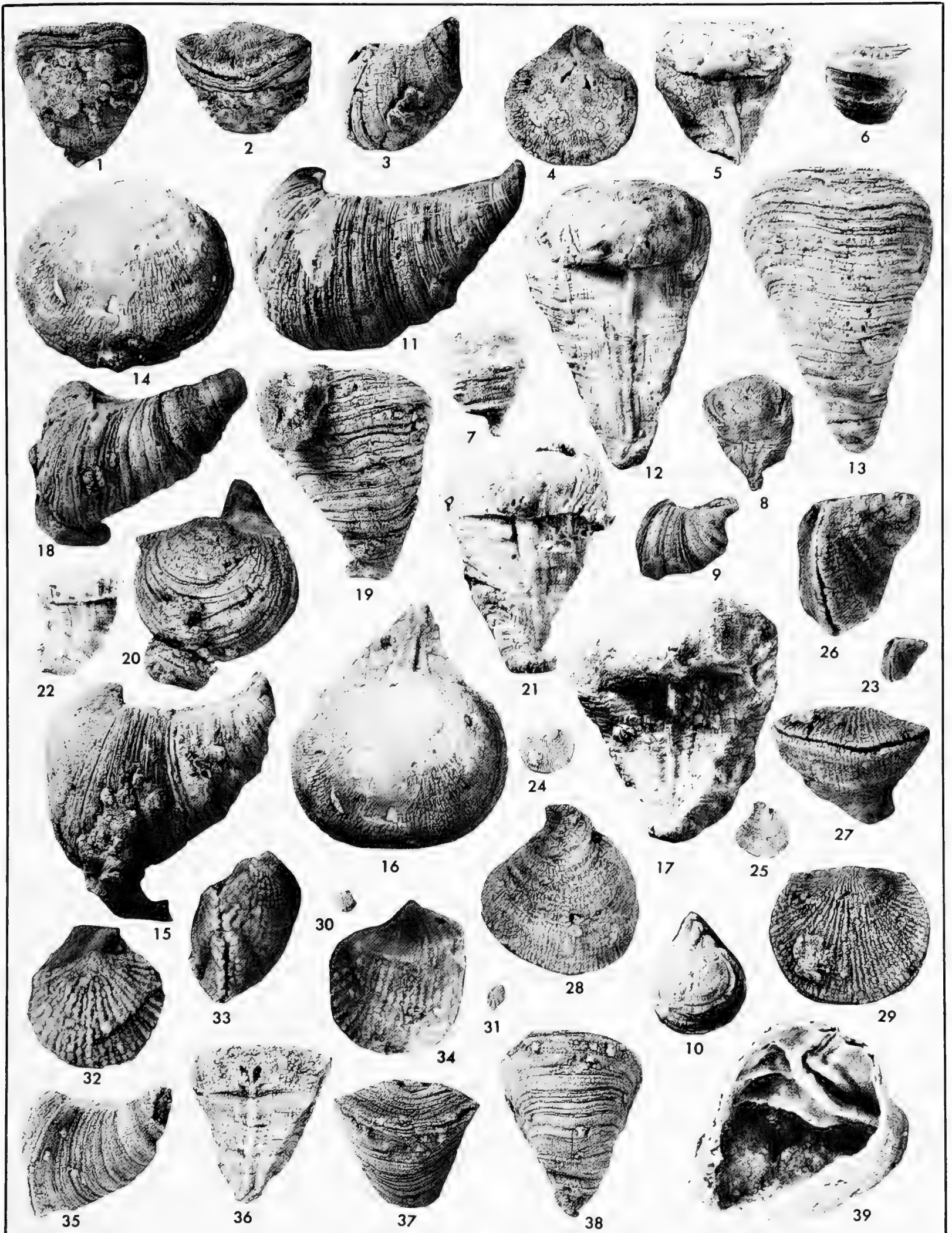
## PLATE 54

*Tropidelasma*

*Tropidelasma rhamphodes*, new species: 1–5, Ventral, anterior, side, dorsal, and posterior views of a young adult,  $\times 1$ , paratype USNM 147882h; 6–10, anterior, ventral, posterior, side, and dorsal views of another young adult,  $\times 1$ , paratype USNM 147882k; 11–13, side, posterior, and anterior views of a large, unusually regular specimen,  $\times 1$ , holotype USNM 147882b; 14–17, dorsal, side, dorsal tilted, and posterior views of a large, fairly regular specimen,  $\times 1$ , paratype USNM 147882a; 18–21, side, anterior, dorsal, and posterior views of a large specimen,  $\times 1$ , paratype USNM 147882d; 22, posterior view of a small adult,  $\times 1$ , paratype USNM 147882j; 23–25, side, dorsal, and ventral views of an immature individual,  $\times 1$ , paratype USNM 147882m; 26–29, side, anterior, ventral, and dorsal views of the preceding specimen,  $\times 3$ ; 30, 31, dorsal and side views of a very young specimen,  $\times 1$ , paratype USNM 147882p; 32–34, dorsal, side, and ventral views of the preceding specimen,  $\times 6$ ; 35–38, side, posterior, anterior, and ventral views of a small adult,  $\times 1$ , paratype USNM 147882f [Skinner Ranch Formation, (Decie Ranch Member), locality USNM 707a].

39, Specimen broken to show long-shafted cardinal process,  $\times 1$ , paratype USNM 147809 [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 714y].

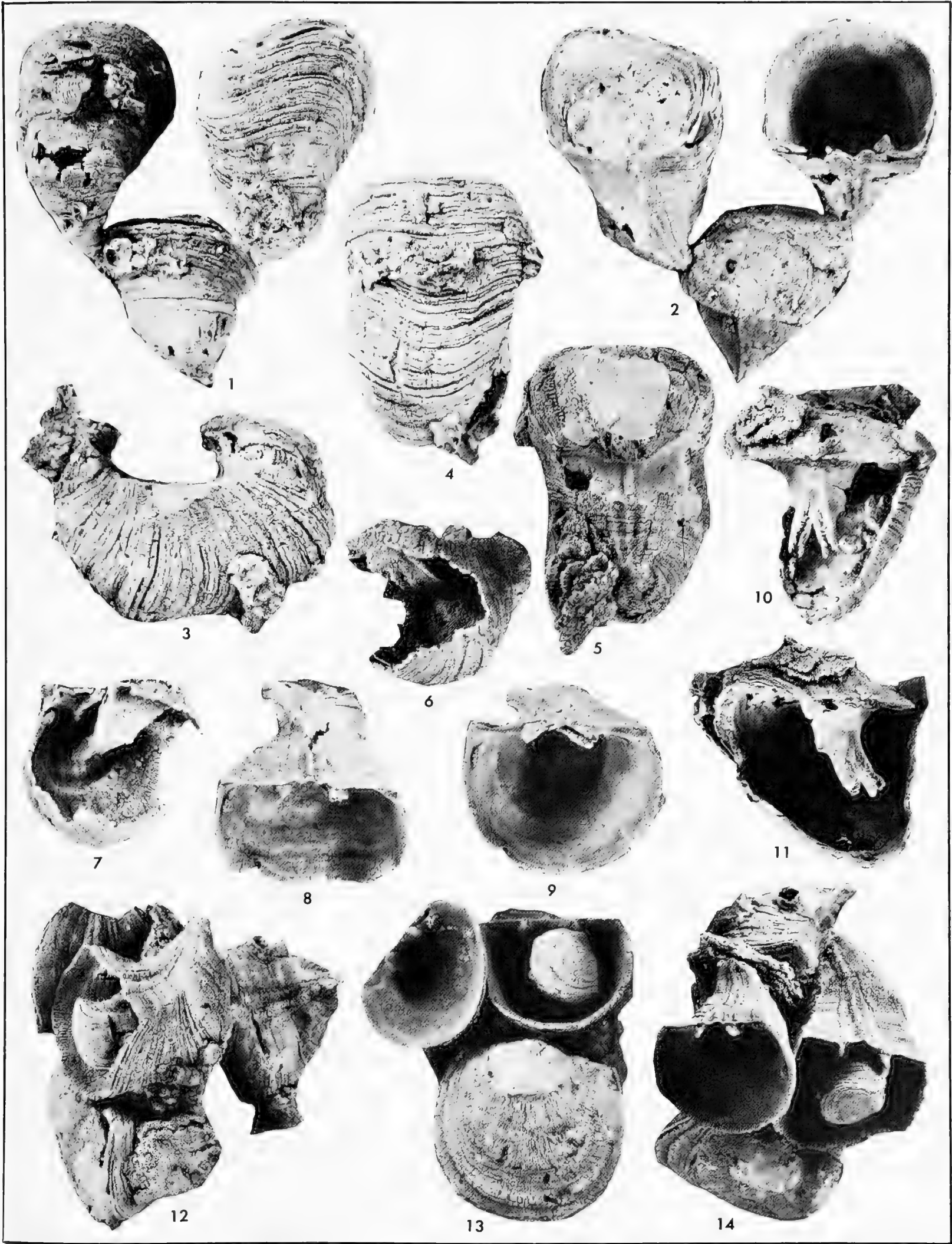


PLATE 54.—*Tropidelasma*.

**PLATE 55***Tropidelasma*

*Tropidelasma rhamphodes*, new species: 1, 2, Ventral and dorsal views of a cluster of three specimens,  $\times 1$ , paratype USNM 147902; 3–5, side, anterior, and posterior views of a misshapen specimen with unusually high brachial valve umbone,  $\times 1$ , paratype USNM 153554a; 6, 7, small broken specimen, showing long-shafted cardinal process,  $\times 1$ , paratype USNM 153554b; 8, 9, interior and posteriorly tilted views of a pedicle valve,  $\times 1$ , paratype USNM 153554c; 10, 11, posterior and partial side view of another broken specimen, showing the cardinal process,  $\times 1$ , paratype USNM 153554d; 12–14, partial side, dorsal, and posterior views of a cluster of several individuals, showing a young one growing inside a pedicle valve,  $\times 1$ , paratype USNM 153554e [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

PLATE 55.—*Tropidelasma*.

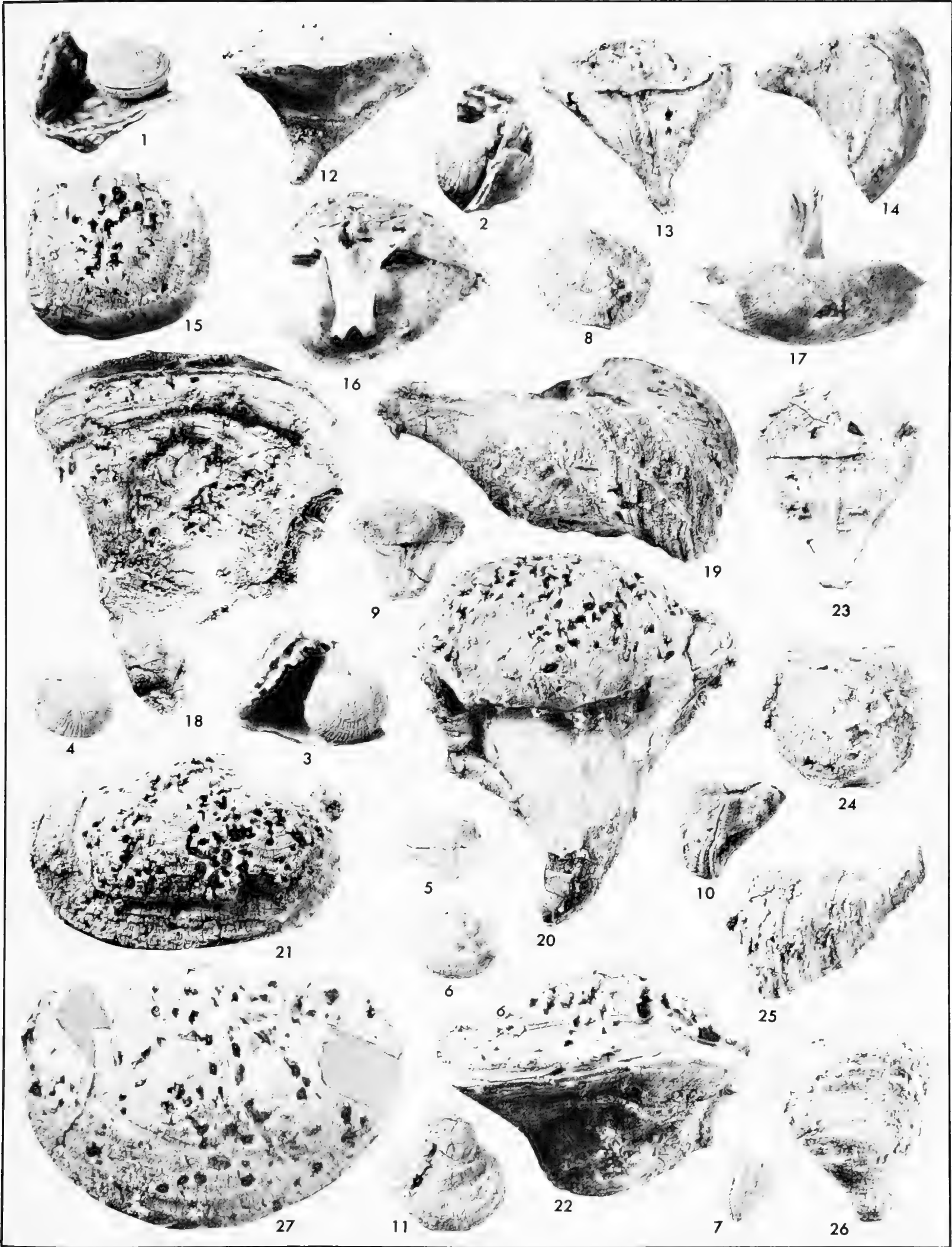


**PLATE 56***Tropidelasma*

*Tropidelasma robertsi*, new species: 1-3. Immature specimen attached to a fragment of *Coscinophora*,  $\times$  1, paratype USNM 153558a; 4-7, dorsal, posterior, ventral, and side views of another immature specimen,  $\times$  1, paratype USNM 153558b; 8-11, dorsal, posterior, side, and ventral views of a larger, immature specimen,  $\times$  1, paratype USNM 153558c; 12-15, anterior, posterior, side, and dorsal views of a specimen with very attenuated beak,  $\times$  1, paratype USNM 153558d; 16, anterior view of the interior, showing the long-shafted cardinal process,  $\times$  1, paratype USNM 153558e; 17, posterior view of another brachial valve, showing the myophore,  $\times$  1, paratype USNM 153558f; 18-22, ventral side, posterior, dorsal, and anterior views of a large adult,  $\times$  1, holotype USNM 153558g; 23-26, posterior, dorsal, side, and ventral views of a narrow, young adult,  $\times$  1, paratype USNM 153558h; 27, exterior of a large dorsal valve, riddled by boring barnacles,  $\times$  1, paratype USNM 153558i [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].



PLATE 56.—*Tropidelasma*.





## PLATE 57

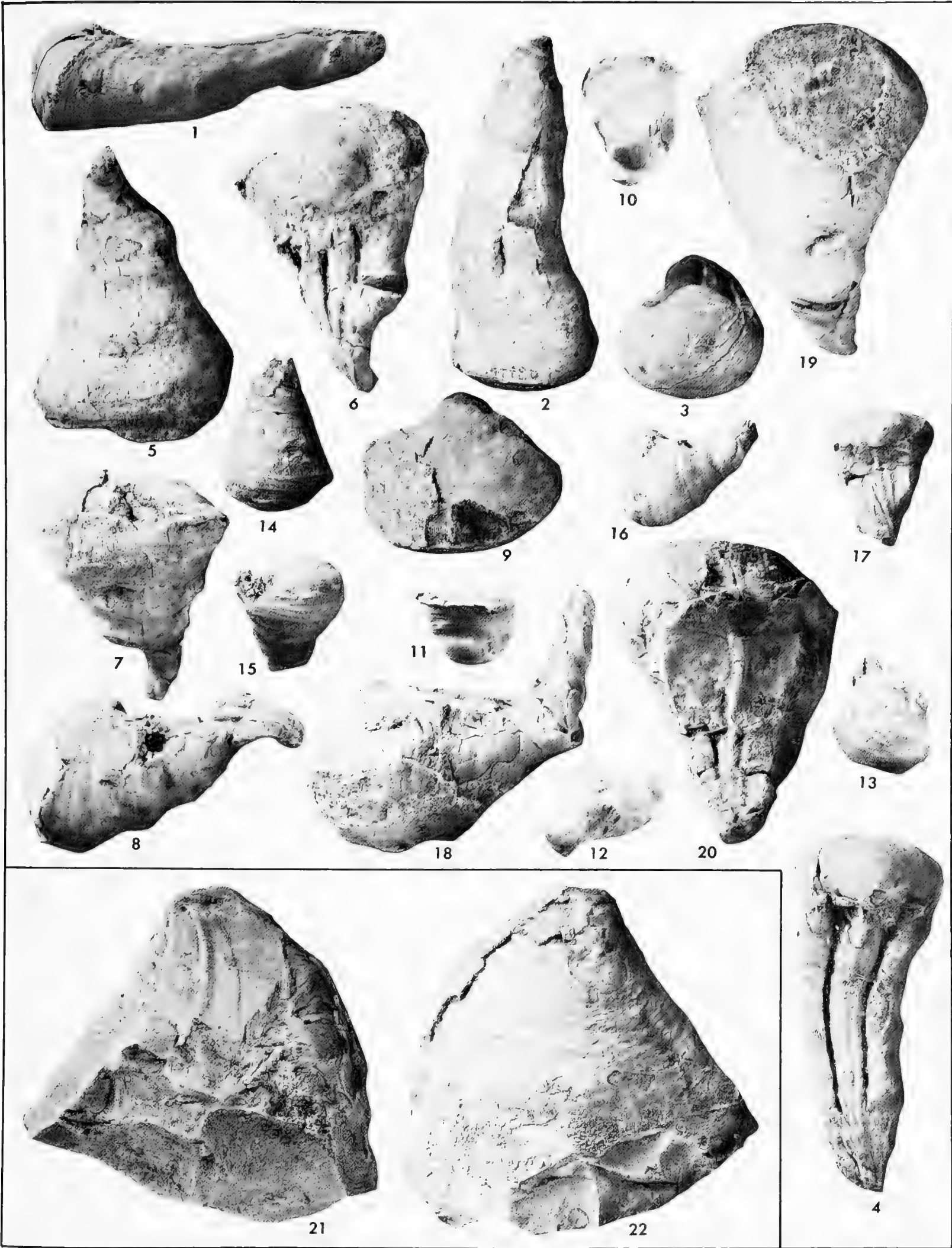
*Tropidelasma*

*Tropidelasma strobilum*, new species: 1-4, Side, ventral, dorsal, and posterior views of a greatly elongated specimen,  $\times 1$ , paratype USNM 147780c; 5-9, ventral, posterior, anterior, side, and dorsal views of a more triangular specimen,  $\times 1$ , holotype USNM 147780b; 14-17, ventral, anterior, side, and posterior views of another small individual,  $\times 1$ , paratype USNM 147780g; 18-20, side, ventral, and posterior views of a large specimen with long narrow beak,  $\times 1$ , paratype USNM 147780a [Lenox Hills Formation, locality USNM 705k].

10-13, Ventral, anterior, side, and dorsal views of a young specimen,  $\times 1$ , paratype USNM 147793 [Lenox Hills Formation, locality USNM 705s].

*Tropidelasma* species 2: 21, 22, Posterior and ventral views of an unusually large and wide species,  $\times 1$ , figured specimen 147888 [Gaptank Formation (*Uddenites*-bearing Shale Member), locality USNM 702q].

PLATE 57.—*Tropidelasma*.



## PLATE 58

*Tropidelasma*

*Tropidelasma curtum*, new species: 1–3, Dorsal, ventral, and side views of a pedicle valve,  $\times 1$ , holotype USNM 152590b; 4–6, side, ventral, and interior views of the holotype,  $\times 2$ ; 7–10, side, interior tilted, exterior, and interior views of a brachial valve,  $\times 1$ , paratype USNM 152590d; 11–14, tilted, exterior, interior, and side views of the preceding paratype,  $\times 2$  [San Andres Formation, locality AMNH B188–8].

*Tropidelasma culmenatum* Cooper and Grant: 15, Side view of a large adult attached by its beak to a bryozoan colony,  $\times 1$ , paratype USNM 147842 [Neal Ranch Formation, locality USNM 701h].

*Tropidelasma costellatum*, new species: 16–19, Ventral, side, posterior, and anterior views,  $\times 1$ , holotype USNM 147823a; 20–23, ventral, posterior, side, and anterior views of the holotype,  $\times 2$ ; 24–26, side, exterior, and posterior views of the brachial valve,  $\times 1$ , paratype USNM 147823d; 27, posterior of the preceding specimen enlarged,  $\times 2$  [Hess Formation (Taylor Ranch Member), locality USNM 702d].

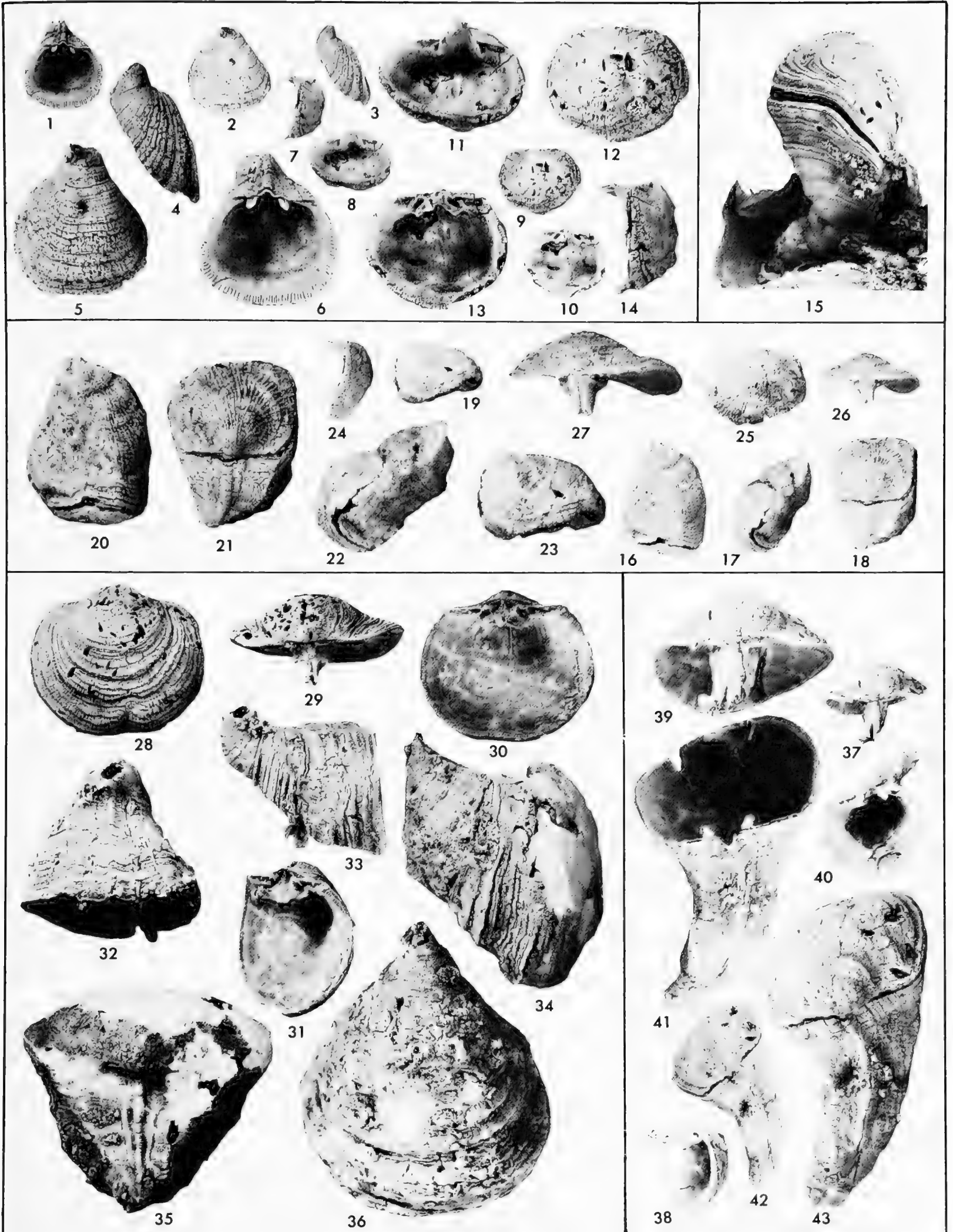
*Tropidelasma corniculum*, new species: 28–31, Exterior, posterior, interior, and partial side views of the brachial valve,  $\times 1$ , paratype USNM 152593 [Road Canyon Formation, locality USNM 721z].

32; 33, Posterior and side views of a pedicle valve,  $\times 1$ , paratype USNM 152592m [Road Canyon Formation, locality USNM 720d].

34–36, Side, posterior, and ventral views of a large specimen,  $\times 1$ , holotype USNM 153562 [Road Canyon Formation, locality USNM 724d].

*Tropidelasma culmenatum* Cooper and Grant: 37, 38, Posterior and side views of the brachial valve belonging to the pedicle valve in figures 41 and 42,  $\times 1$ , paratype USNM 147839; 39, posterior of the preceding specimen,  $\times 2$ ; 40, interior of the pedicle valve,  $\times 1$ , paratype USNM 147839; 41, posterior view of the pedicle valve, showing the strong teeth,  $\times 2$ ; 42, 43, the complete specimen,  $\times 1$ ,  $\times 2$ , paratype USNM 147839 [Neal Ranch Formation, locality USNM 701h].

PLATE 58.—*Tropidelasma*.



## PLATE 59

*Tropidelasma*

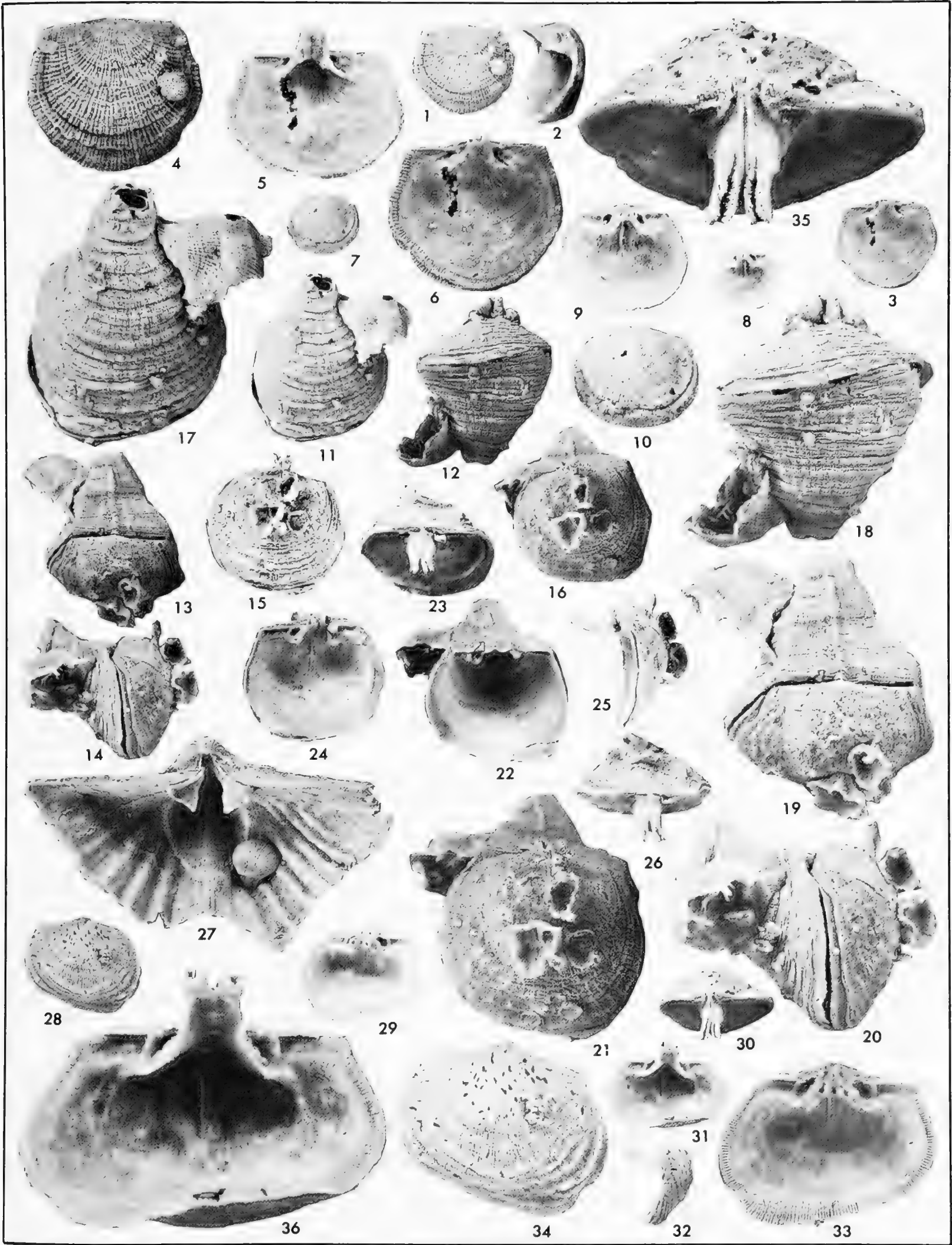
*Tropidelasma anthicum*, new species: 1-3, Dorsal, side, and interior views of a small brachial valve,  $\times 1$ , paratype USNM 153555a; 4-6, exterior, interior tilted, and interior views of the preceding specimen showing the cardinalia and ornament,  $\times 2$ ; 7, 8, exterior and interior views of another small brachial valve,  $\times 1$ , paratype USNM 153555b; 9, 10, interior and exterior views of the preceding specimen,  $\times 2$  [Word Formation (Willis Ranch Member), locality USNM 706e]

11-16, Ventral, anterior, posterior, side, dorsal, and posteriorly tilted views,  $\times 1$ , holotype, USNM 147861a; 17-21, ventral, anterior, posterior, and side and dorsal views of the holotype,  $\times 1.5$ ; 22, interior of the pedicle valve of the holotype,  $\times 1$ ; 23-26, posterior tilted, interior, side, and posterior views of the brachial valve of the holotype, showing the cardinalia,  $\times 1$ ; 28-32, exterior, interior, posterior, interior tilted posteriorly, and side views of a brachial valve,  $\times 1$ , paratype USNM 147861d; 33, 34, interior and exterior of the preceding specimen,  $\times 2$ ; 35, 36, posterior and interior views of the same specimen as preceding, showing the cardinalia,  $\times 3$  [Word Formation (lens between the Willis Ranch and Appel Ranch Members), locality USNM 706b].

27, Young individual attached inside *Neospirifer*,  $\times 1$ , paratype USNM 153556 [Word Formation (China Tank Member), locality USNM 706c].



PLATE 59.—*Tropidelasma*.



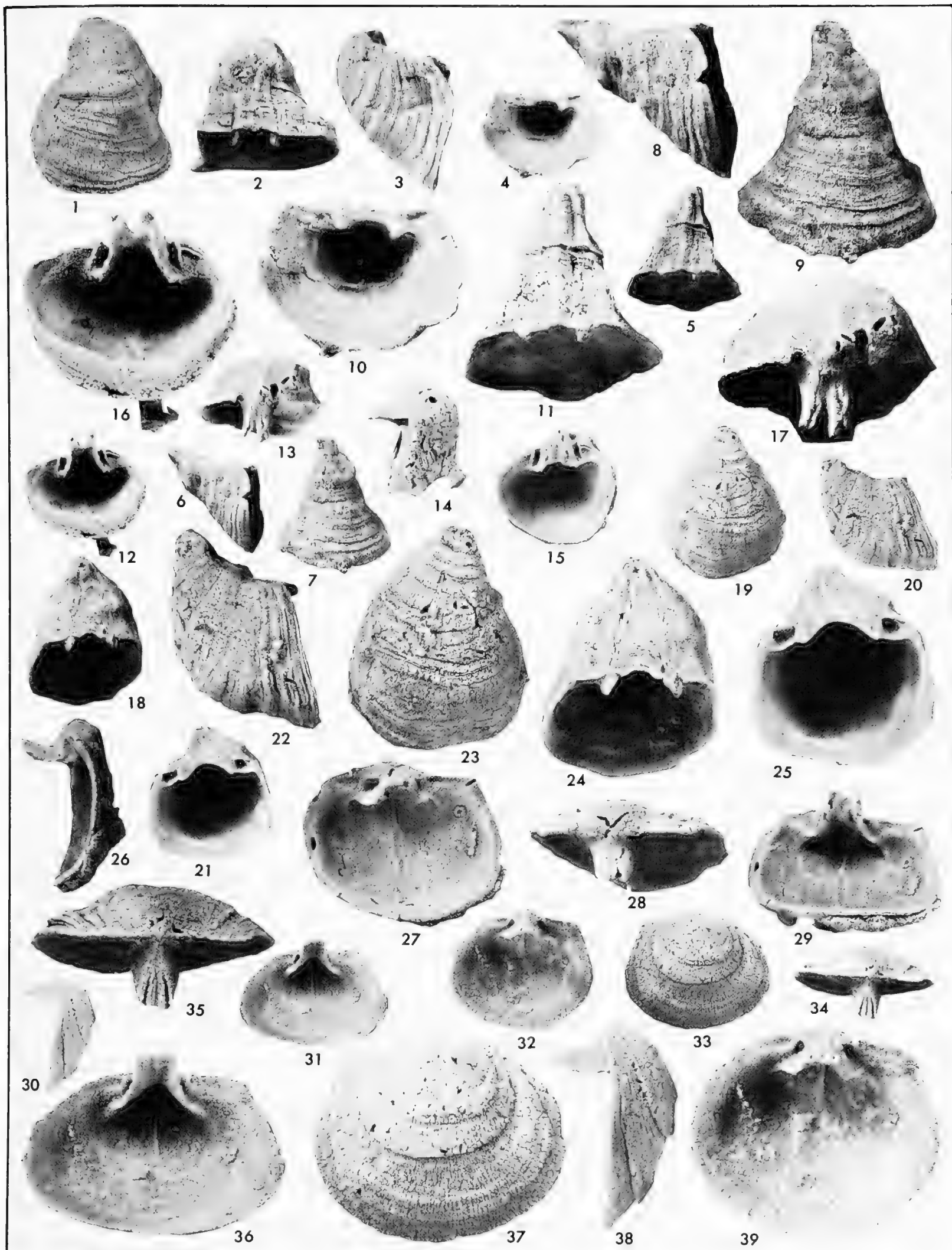
## PLATE 60

*Tropidelasma*

*Tropidelasma anthicum*, new species: 1-3, Ventral, posterior, and side views of a pedicle valve,  $\times 1$ , paratype USNM 153557a; 26-29, side, interior, posterior and posteriorly tilted views of a brachial valve,  $\times 1$ , paratype USNM 153557b; 30-34, side, posteriorly tilted, interior, exterior, and posterior views of a smaller brachial valve,  $\times 1$ , paratype USNM 153557c; 35-39, posterior, interior posteriorly tilted, exterior, side, and interior views of the preceding specimen,  $\times 2$  [Word Formation (China Tank Member), locality USNM 726r].

4-7, Interior, posterior, side, and ventral views of a small, narrowly conical pedicle valve,  $\times 1$ , paratype USNM 147861g, 8-11, side, ventral, interior, and posterior views of the preceding specimen,  $\times 2$ ; 12-15, posteriorly tilted, posterior, side, and interior views of a thick brachial valve,  $\times 1$ , paratype USNM 147861e; 16, 17, the preceding specimen posteriorly tilted to show the cardinalia and posterior,  $\times 2$ ; 18-21, posterior, ventral, side, and interior views of a pedicle valve,  $\times 1$ , paratype USNM 147861b; 22-25, side, ventral, posterior and interior views of the preceding,  $\times 1.5$  [Word Formation (lens between the Willis Ranch and Appel Ranch Members), locality USNM 706b].

PLATE 60.—*Tropidelasma*.



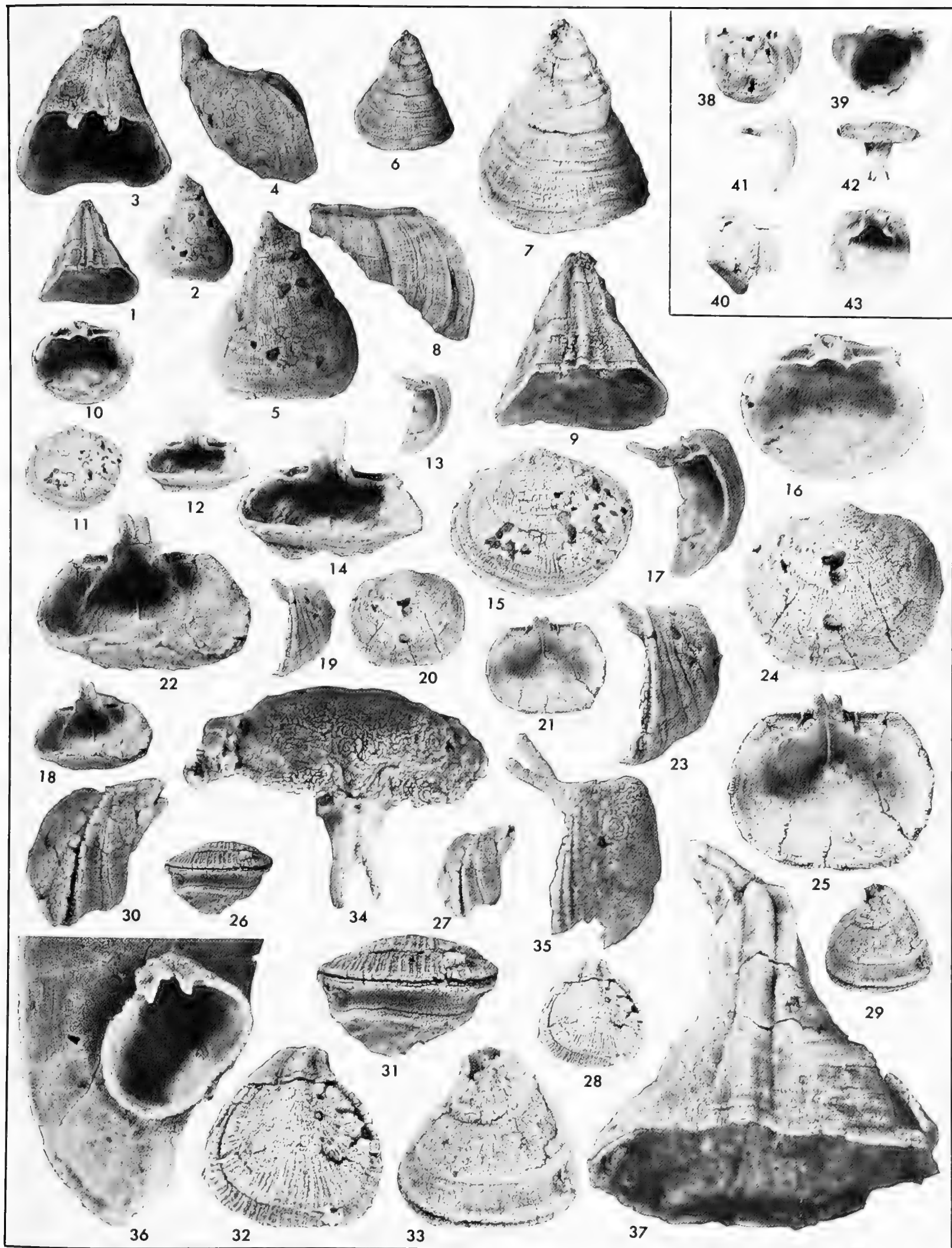
## PLATE 61

*Tropidelasma*

*Tropidelasma gregarium* (Girty): 1, 2, Dorsal and ventral views of a pedicle valve,  $\times$  1, hypotype USNM 152591d; 3–5, dorsal, side, and ventral views of the preceding specimen,  $\times$  2; 6, ventral view of another fairly symmetrical pedicle valve,  $\times$  1, hypotype USNM 152591e; 7–9, ventral, side, and posterior views of the preceding specimen,  $\times$  2; 10–13, interior, exterior, anterior, and side views of a brachial valve,  $\times$  1, hypotype USNM 152591–1; 14–17, anterior, exterior, side, and interior views of the preceding specimen,  $\times$  2; 18–21, anterior, side, exterior, and interior views of another brachial valve,  $\times$  1, hypotype USNM 152591n; 22–25, anterior, side, exterior, and interior views of the preceding specimen,  $\times$  2; 26–29, anterior, side, dorsal, and ventral views of a complete specimen,  $\times$  2, hypotype USNM 152591a; 30–33, side, anterior, dorsal, and ventral views of the preceding specimen,  $\times$  3; 34, 35, posterior and side views, showing slender cardinal process,  $\times$  4, hypotype USNM 152591o; 36, pedicle valve attached to another brachiopod shell,  $\times$  2, hypotype USNM 152591p; 37, posterior view of a pedicle valve with greatly elongated beak,  $\times$  3, hypotype USNM 152591q [Bell Canyon Formation (Lamar Member), locality USNM 738b].

*Tropidelasma* species 4: 38–40, Posterior, interior, and side views of a fragmentary pedicle valve,  $\times$  1, figured specimen USNM 152601a; 41–43, side, posterior, and interior views of a brachial valve,  $\times$  1, figured specimen, USNM 152601b [Cathedral Mountain Formation, locality USNM 721u].



PLATE 61.—*Tropidelasma*.



## PLATE 62

*Derbyoides, Ombonia, Bothrostegium, and Dielasma*

*Derbyoides* species 1: 1, 2. Dorsal and ventral views of a nearly complete specimen,  $\times 1$ , figured specimen USNM 153801 [Gaptank Formation, locality USNM 701y].

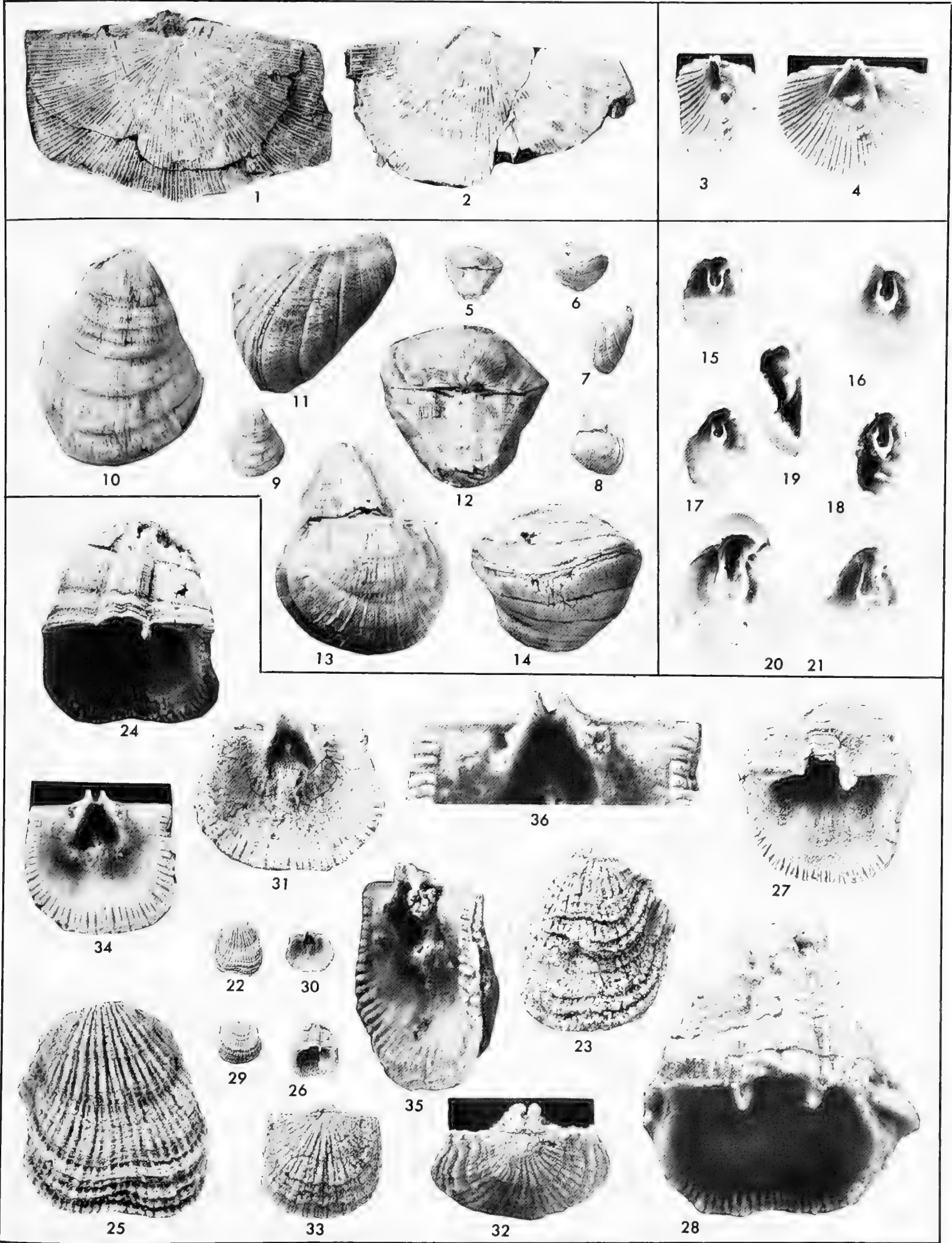
*Ombonia invecta*, new species: 3, 4. Laterally tilted and interior views of a small brachial valve, showing cardinalia,  $\times 3$ , paratype USNM 150995-1 [Road Canyon Formation, locality USNM 720d].

*Bothrostegium derbyoideum*, new species: 5-9, Posterior, anterior, side, dorsal and ventral views,  $\times 1$ , paratype USNM 153338; 10-14, ventral, side, posterior, dorsal, and anterior views of the same specimen,  $\times 3$  [Road Canyon Formation, locality USNM 721t].

*Dielasma compactum*, new species: 15-19, Ventral view of the interior of five young specimens, showing loop in centronelliform stage, the first three and the fifth  $\times 4$ , the fourth  $\times 3$ , paratypes USNM 154527d, c, i, f, and b; 20, 21, interior of two specimens, showing early development of the median fold in the transverse band,  $\times 3$ , paratypes USNM 154527h and j [Word Formation (Willis Ranch Member), locality USNM 706].

*Bothrostegium compactum*, new species: 22, 25, Exterior of a pedicle valve,  $\times 1$ ,  $\times 4$ , holotype USNM 152599b; 24, 26, interior, exterior of same specimen,  $\times 4$ ,  $\times 1$ ; 23, 27, exterior and interior of another pedicle valve,  $\times 4$ , paratype USNM 152599a; 28, posterior of another pedicle valve, showing ponderous teeth and thick pseudodeltidium,  $\times 6$ , paratype USNM 152599i; 29, 30, exterior and interior of a brachial valve,  $\times 1$ , paratype USNM 152599e; 31, interior of same specimen,  $\times 4$ ; 32, posterior of same, showing myophore,  $\times 3$ ; 33, exterior of another brachial valve,  $\times 3$ , paratype USNM 152599j; 34, interior of same, showing deep muscle impressions and thickened cardinalia,  $\times 4$ ; 35, 36, laterally tilted and interior views of the same specimen showing the cardinalia,  $\times 6$  [Road Canyon Formation, locality USNM 703c].

PLATE 62.—*Derbyoides*, *Ombonia*, *Bothrostegium*, and *Dielasma*.

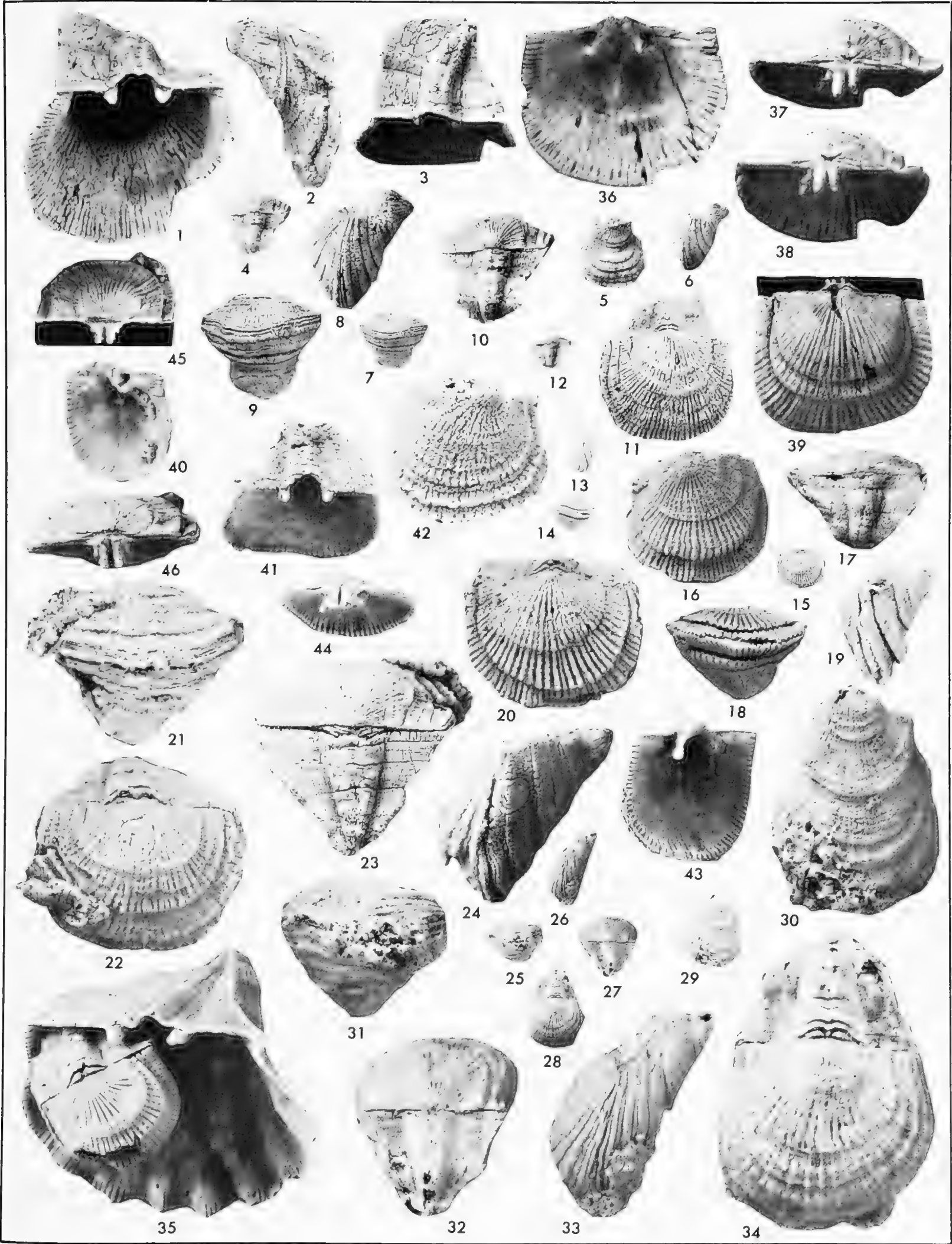


## PLATE 63

*Bothrostegium*

*Bothrostegium derbyoideum*, new species: 1-3, Interior,  $\times 3$ , and side and posterior views of a pedicle valve,  $\times 2$ , showing sulcate pseudodeltidium, paratype USNM 147891a; 4-7, posterior, ventral, side, and anterior views,  $\times 1$ , paratype USNM 152595b; 8-11, side, anterior, and posterior views,  $\times 1.5$ , and dorsal view  $\times 2$ , of the paratype; 12-15, posterior, side, anterior, and dorsal views of a small specimen;  $\times 1$ , paratype USNM 152595d; 16-19, ventral, posterior, anterior, and side views of the preceding,  $\times 3$ ; 20, dorsal view of the preceding,  $\times 4$ ; 21-24, anterior, dorsal, posterior, and side views of a large specimen,  $\times 3$ , paratype USNM 152595a; 25-29, anterior, side, posterior, dorsal, and ventral views of the holotype, USNM 152596a; 30-34, ventral, anterior, posterior, and side views,  $\times 3$ , and dorsal view,  $\times 4$ , of the holotype; 35, specimen adhering to the inside of a *Meekella* shell in its attached growth position,  $\times 3$ , paratype USNM 147891c; 36-38, interior,  $\times 4$ , and two posterior positions,  $\times 3$ , of the brachial valve, showing the cardinal process, paratype USNM 152596c; 39, exterior of a brachial valve,  $\times 4$ ; paratype 152596d; 40, same tilted sideways to show deep socket,  $\times 3$ ; 41, 42, interior and exterior of a pedicle valve, showing strong teeth,  $\times 3$ , paratype USNM 152597a; 43, brachial valve laterally tilted to show sockets and cardinalia,  $\times 4$ , paratype USNM 147891b; 44, posterior of same,  $\times 3$ ; 45, 46, posterior views of the cardinalia,  $\times 3$ ,  $\times 4$ , paratype USNM 152598b [Road Canyon Formation, localities: figures 1-3, 35, 43, 44 = USNM 710u; 4-24 = USNM 721y; 25-34, 36-40 = USNM 721t; 41, 42 = USNM 724b; 45, 46 = USNM 721w].

PLATE 63.—*Bothrostegium*.



## PLATE 64

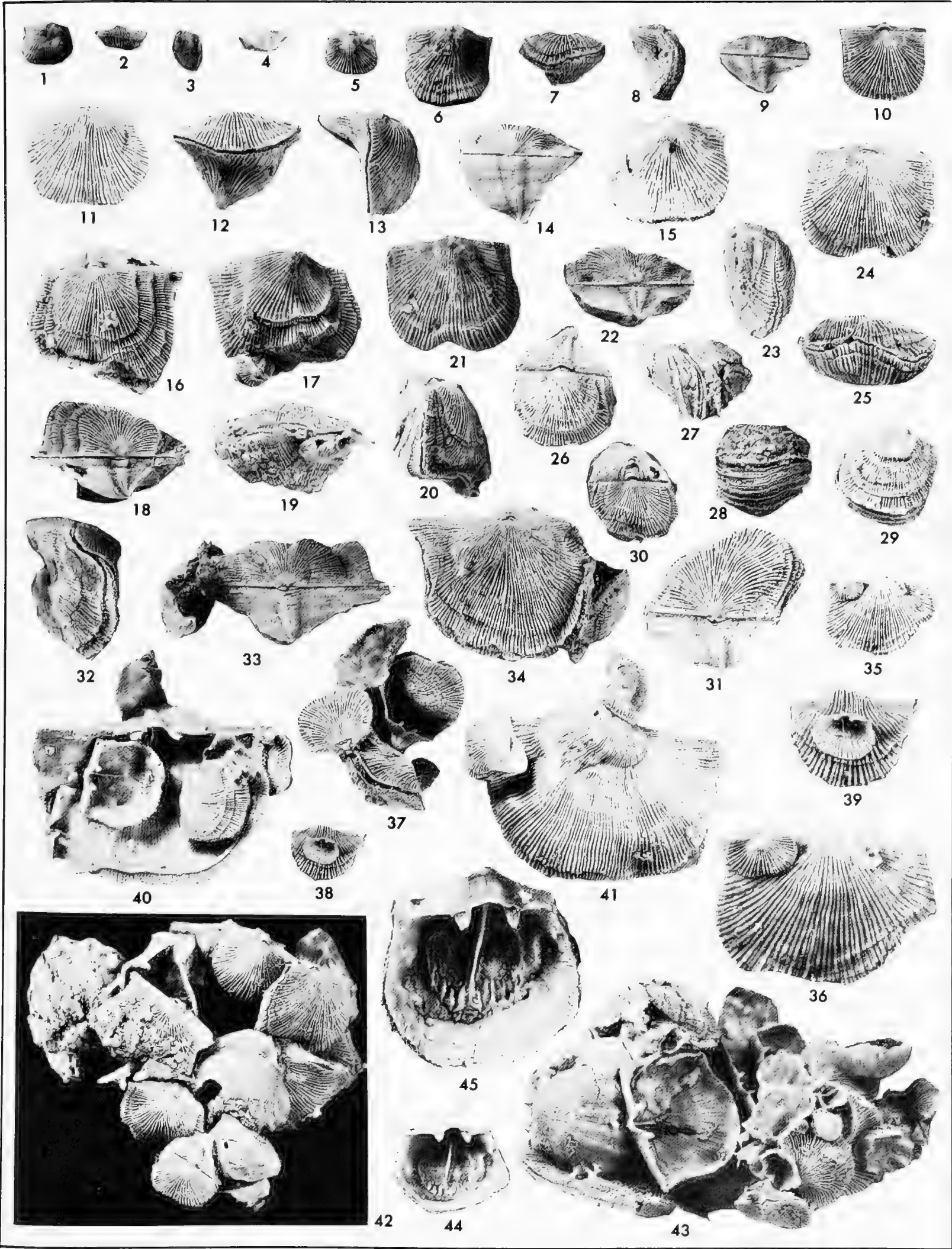
*Derbyia*

*Derbyia bella*, new species: 1-5, Ventral, anterior, side, posterior, and dorsal views of an immature specimen,  $\times 1$ , paratype USNM 153189a; 6-10, same views of a larger specimen,  $\times 1$ , paratype USNM 151025h; 11-15, dorsal, anterior, side, posterior, and ventral views of a still larger specimen,  $\times 1$ , paratype USNM 153189b; 16-20, dorsal, ventral, posterior, anterior, and side views,  $\times 1$ , holotype USNM 151025c; 21-25, ventral, posterior, side, dorsal, and anterior views, showing median depression in pseudodeltidium,  $\times 1$ , paratype USNM 151025e; 26-29, dorsal, side, anterior, and ventral views of a small obese specimen, showing much anterior growth,  $\times 1$ , paratype USNM 153189c; 30, dorsal view of a small specimen with exceptional broad interarea,  $\times 1$ , paratype USNM 153189d; 31, posterior of a distorted specimen, showing pseudodeltidium with median groove toward the apex,  $\times 1$ , paratype USNM 153189e; 32-34, side, posterior, and dorsal views of a large specimen,  $\times 1$ , paratype USNM 151025b; 35, 36, views of two immature specimens attached to an adult,  $\times 1$ ,  $\times 2$ , paratype USNM 153285b; 37, cluster of immature specimens attached to one another,  $\times 1$ , paratype USNM 153279a; 38, 39, views of a small pedicle valve attached to another young specimen,  $\times 1$ ,  $\times 2$ , paratype USNM 153279b; 42, a cluster of larger specimens,  $\times 1$ , paratype USNM 153279c; 43, another cluster of attached specimens of assorted sizes,  $\times 1$ , paratype USNM 153279d; 44, 45, views of a pedicle valve interior, showing median septum and strong teeth,  $\times 1$ ,  $\times 2$ , paratype USNM 153189f [Neal Ranch Formation (bed 4 of P. B. King), USNM 701-1].

40, Pedicle valve of *Derbyia carteri* with several small specimens of *D. bella* cemented to it,  $\times 1$ , paratype USNM 153285a; 41, exterior of same pedicle valve,  $\times 1$  showing other attached specimens and the attachment of the host *D. carteri* to a small *D. bella* [Neal Ranch Formation (bed 4 of P. B. King), USNM 727e].



PLATE 64.—*Derbyia*.



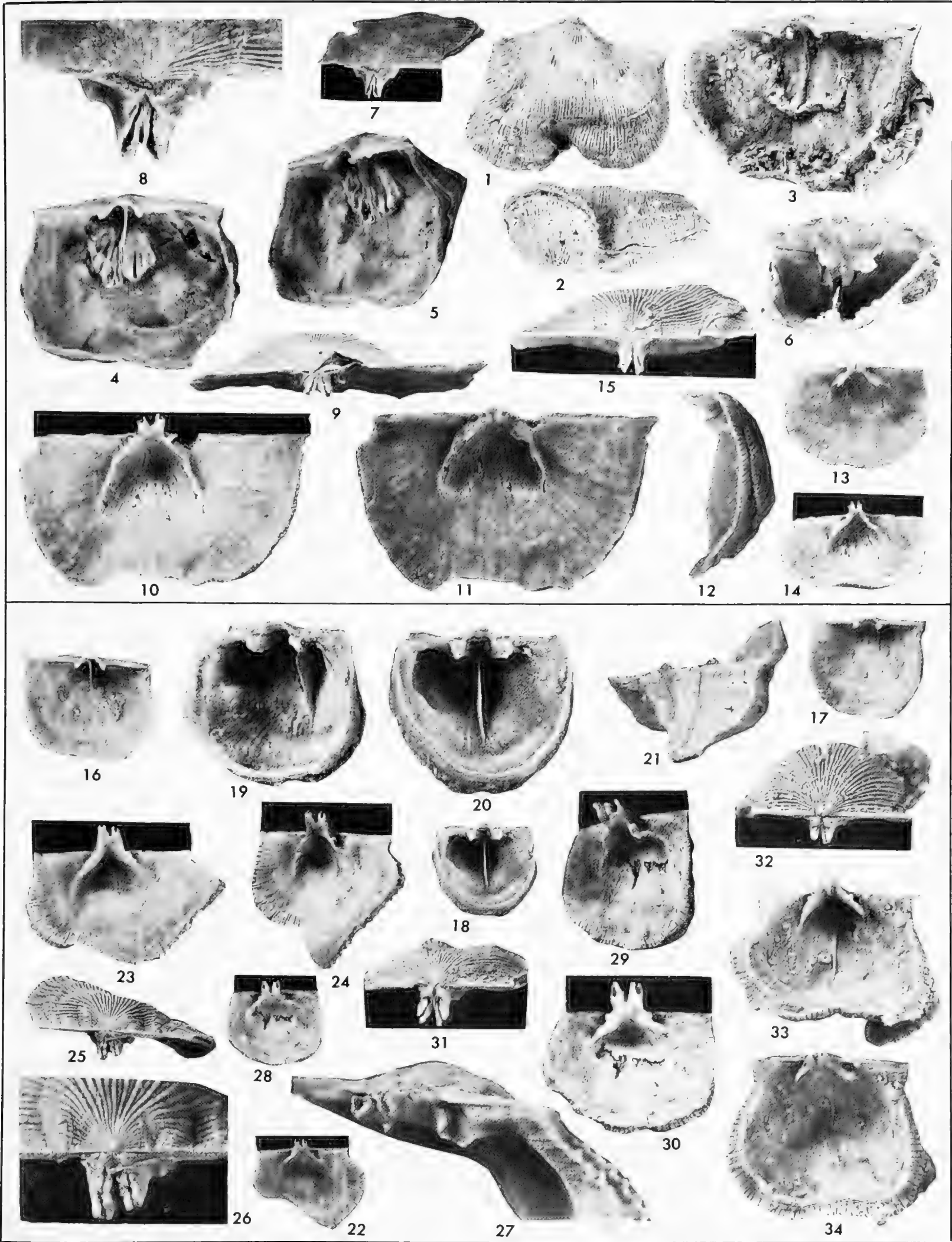
## PLATE 65

*Derbyia*

*Derbyia carteri*, new species: 1, 2, Ventral and anterior views of a specimen deformed by growing against a bryozoan,  $\times 1$ , paratype USNM 153281a; 3, interior of the pedicle valve slightly tilted to the side to show the thickened anterior rim around the muscle scars,  $\times 1$ , paratype USNM 153281b; 4, 5, another pedicle valve interior in full view and slightly tilted to show thickened muscle region,  $\times 1$ , paratype USNM 153281c; 6, posterior of the interior of a complete specimen, showing the relationship of the median septum to the cardinal process,  $\times 1$ , paratype USNM 153281d; 7, 8, views of the posterior of a brachial valve, showing the cardinal process, its myophores, and the remnant of a chilidium,  $\times 1$ ,  $\times 3$ , paratype USNM 153281e; 9–12, posterior, interior tilted, full view, and side views of an adult brachial valve,  $\times 1$ , paratype USNM 153281f; 13, 14, full and posteriorly tilted views of a small brachial valve, showing cardinal process and supporting plates,  $\times 1$ , paratype USNM 153281g; 15, posterior of the preceding specimen,  $\times 2$  [Neal Ranch Formation (bed 4), USNM 701d].

*Derbyia bella*, new species: 16, 17, full and tilted views of a pedicle valve interior,  $\times 1$ , paratype USNM 153280a; 18, full view of the pedicle valve interior,  $\times 1$ , paratype USNM 153280b; 19–21, the same specimen in tilted and full views to show the septum, teeth, and long interarea,  $\times 2$ ; 22, full view of the interior of a misshapen brachial valve,  $\times 1$ , paratype USNM 153280c; 23–25, anteriorly tilted, laterally tilted, and posterior views of the same specimen,  $\times 2$ ; 26, 27, posterior and lateral views of the cardinal process of the same specimen, showing chilidium, myophore, and socket,  $\times 4$ ; 28, full view of another brachial valve with much thickened cardinal process,  $\times 1$ , paratype USNM 153280d; 29–31, same specimen in laterally tilted, posteriorly tilted, and posterior views, showing the myophore slits and chilidium,  $\times 2$ ; 32–34, posterior, posteriorly tilted, and full views of another brachial valve, showing chilidium, supporting plates, and adductor myophragm,  $\times 2$ , paratype USNM 153280e [Neal Ranch Formation (bed 4 of P. B. King), USNM 701–1].

PLATE 65.—*Derbyia*.



## PLATE 66

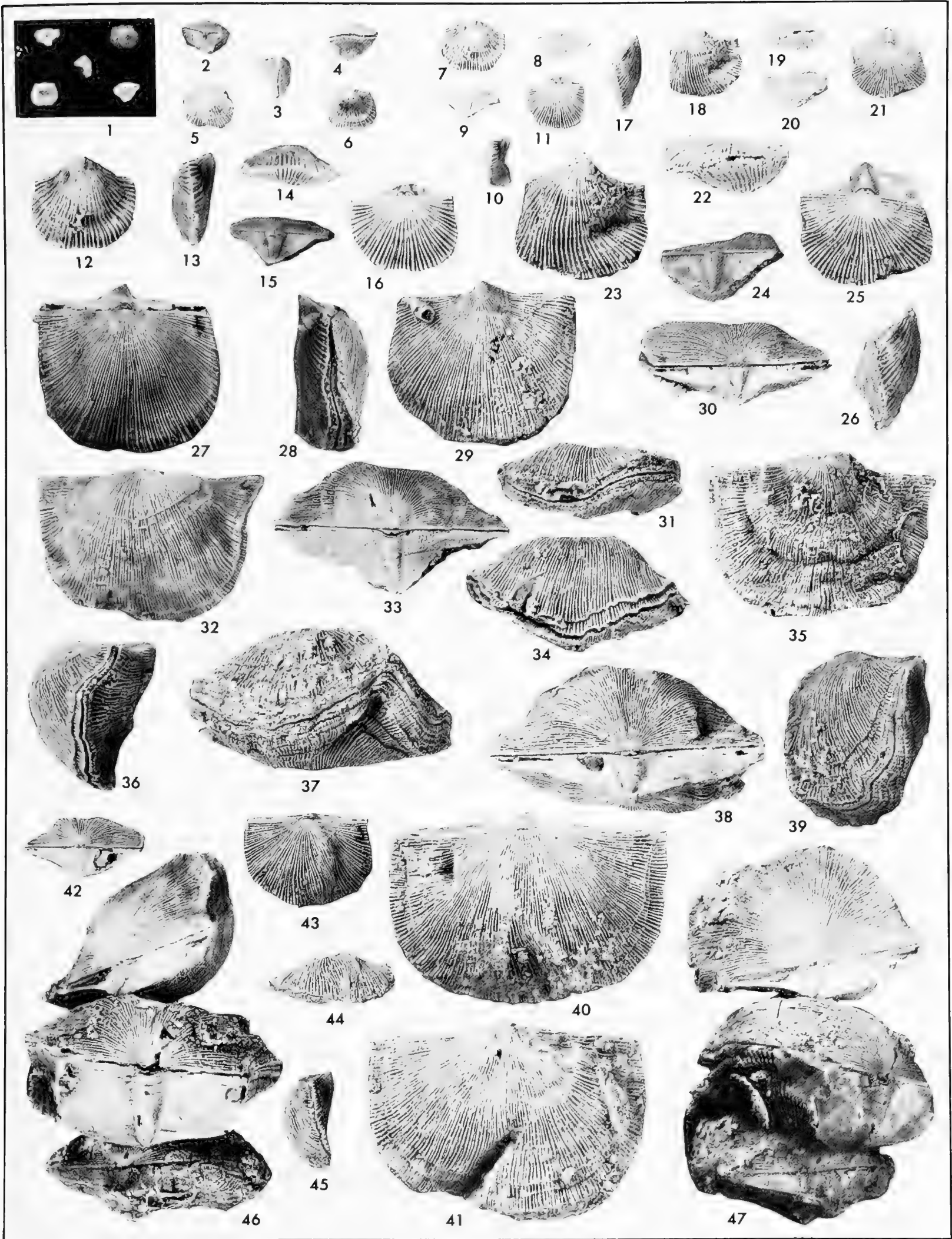
*Derbyia*

*Derbyia carteri*, new species: 1, Posterior, dorsal, side, ventral, and anterior views of an immature specimen,  $\times 1$ , paratype USNM 153282a; 2-6, posterior, side, anterior, dorsal, and ventral views of the same specimen,  $\times 2$ ; 7-11, ventral, anterior, posterior, side, and dorsal views of a larger specimen,  $\times 1$ , paratype USNM 153282b; 12-16, ventral, side, anterior, posterior, and dorsal views of the preceding,  $\times 2$ ; 17-21, side, ventral, anterior, posterior, and dorsal views of a still larger specimen,  $\times 1$ , paratype USNM 153282c; 22-26, anterior, ventral, posterior, dorsal, and side views of the preceding,  $\times 2$ ; 46, 47, cluster of attached adults,  $\times 1$ , paratype USNM 153283 [Neal Ranch Formation (equivalent of bed 4 of P. B. King), USNM 701d].

27-31, Dorsal, side, ventral, posterior, and anterior views of a nearly adult specimen,  $\times 1$ , paratype USNM 151020f; 32-36, dorsal, posterior, anterior, ventral, and side views of a medium-sized adult,  $\times 1$ , paratype USNM 151020c; 37-41, anterior, posterior, side, dorsal, and ventral views of the holotype, showing effects of impingement against a branch of bryozoan,  $\times 1$ , USNM 151020a; 42-45, posterior, dorsal, anterior, and side views of a small specimen,  $\times 1$ , 151020j [Neal Ranch Formation (bed 12) USNM 701k].



PLATE 66.—*Derbyia*.





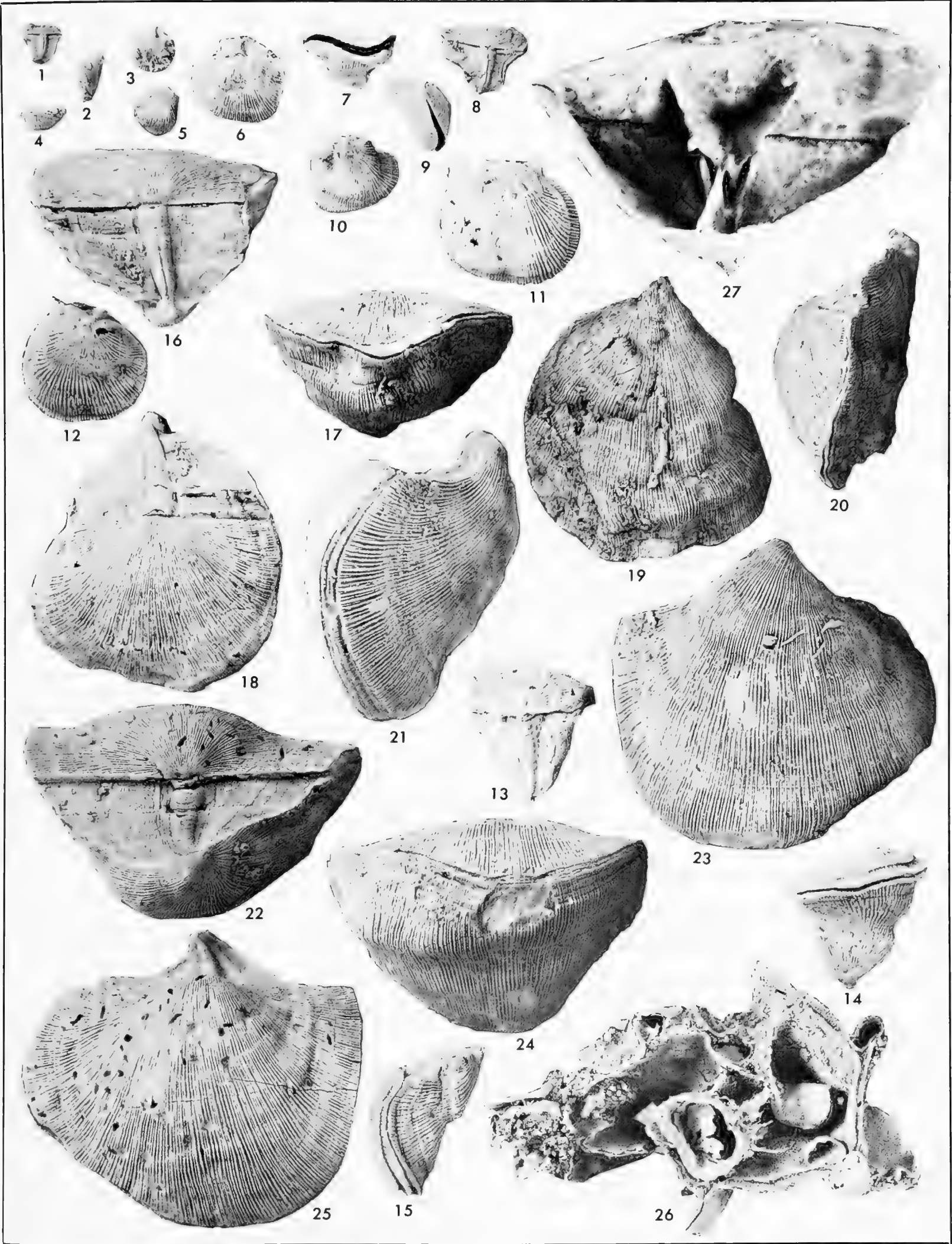
## PLATE 67

*Derbyia*

*Derbyia profunda*, new species: 1–5, Posterior, side, dorsal, anterior, and ventral views of an immature specimen,  $\times 1$ , paratype USNM 151015c; 6–10, dorsal, anterior, posterior side and ventral views of a larger paratype,  $\times 1$ , USNM 151015e; 11–15, dorsal, ventral, posterior, anterior, and side views,  $\times 1$ , of a still larger paratype, USNM 151015g; 16–20, posterior, anterior, dorsal, ventral, and side views of a nearly full grown paratype,  $\times 1$ , 151015j; 21–25, side, posterior, ventral, anterior, and dorsal views of a fully grown adult,  $\times 1$ , holotype USNM 153348; 27, broken specimen, showing cardinal process, median septum, and dental ridges,  $\times 1$ , paratype USNM 153347a [Neal Ranch Formation (beds 12–14 of P. B. King), USNM 701k].

26, Young specimen nestled in a niche of a bryozoan,  $\times 1$ , paratype USNM 153349 (note associated *Teguliferina* and *Diplanus*) [Neal Ranch Formation (beds 12–14 of P. B. King), USNM 701h].

PLATE 67.—*Derbyia*.



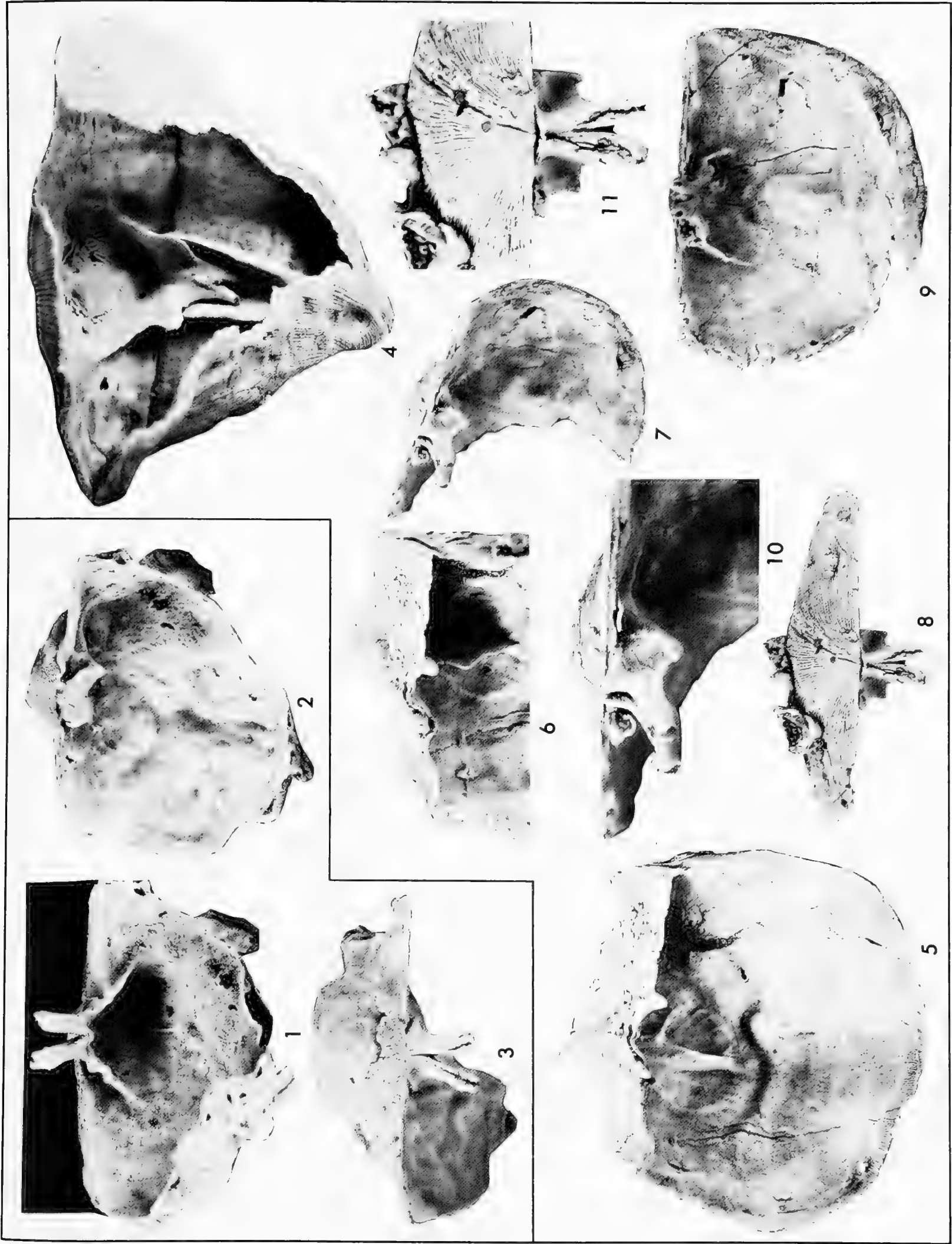
## PLATE 68

*Derbyia*

*Derbyia pannucia*, new species: 1-3, Posteriorly tilted, laterally tilted, and posterior views of a brachial valve, showing supporting plates and long prongs of the cardinal process,  $\times 1$ , paratype USNM 151122r [Word Formation (Willis Ranch Member, upper), USNM 706e].

*Derbyia profunda*, new species: 4, Imperfect specimen, showing cardinal process and dental ridges,  $\times 2$ , paratype USNM 153347c; 5, 6, pedicle valve interior and tilted laterally to show median septum,  $\times 1$ , paratype USNM 153347b; 7-9, brachial valve tilted laterally, in posterior view and interior view, showing the cardinal process,  $\times 1$ , paratype USNM 153847a; 10, 11, lateral and posterior views of the cardinal process of the preceding specimen, showing the vestigial chilidium and the forked myophore,  $\times 2$  [Neal Ranch Formation (beds 12-14 of P. B. King), USNM 701k].

PLATE 68.—*Derbyia*.



## PLATE 69

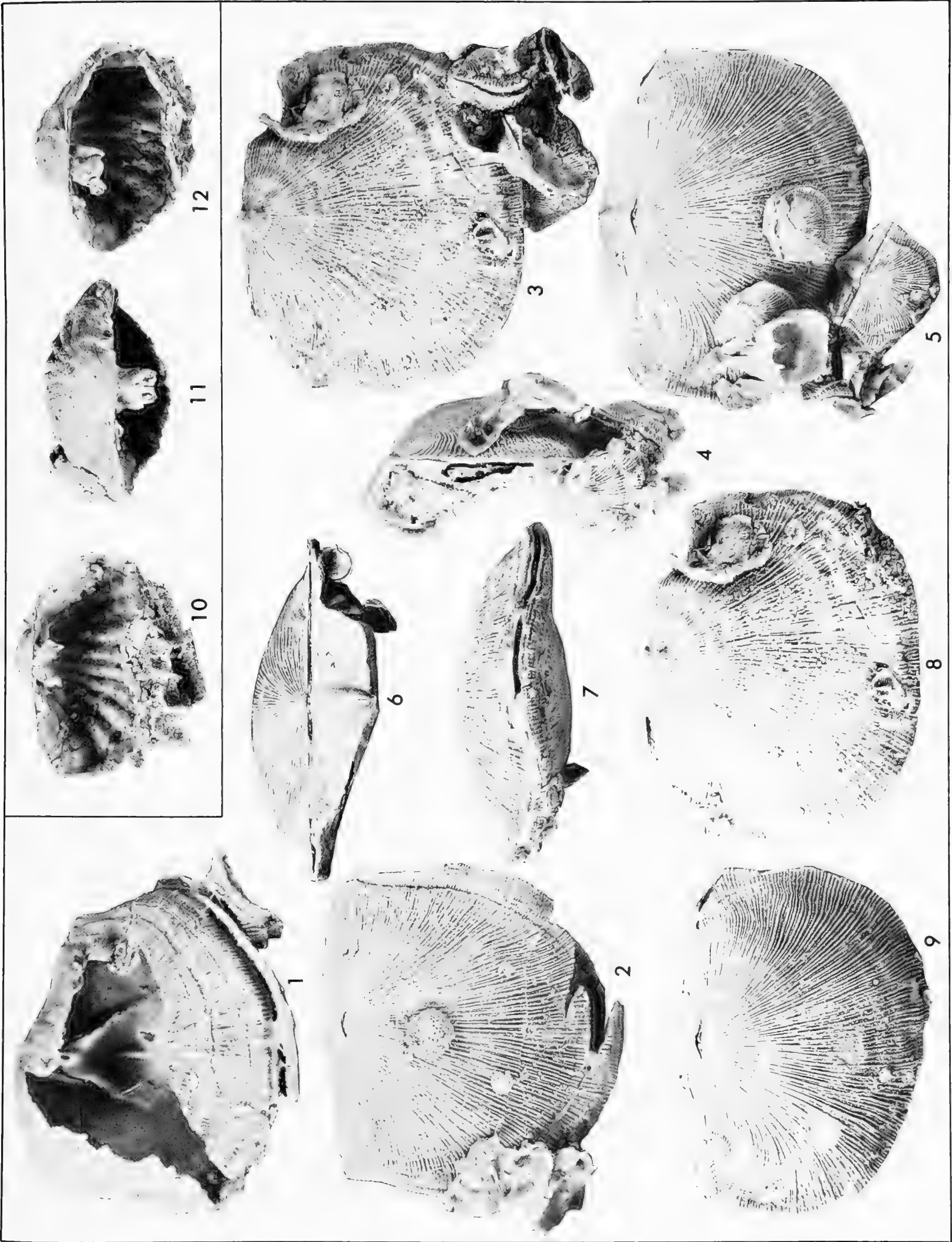
*Derbyia* and *Meekella*

*Derbyia strophomenoidea*, new species: 1, 2, Ventral and dorsal views of a broken specimen, showing the exterior and the cardinal process of the interior,  $\times 1$ , paratype USNM 151213a; 3–5, large specimen encrusted by specimens of *Derbyia bella*,  $\times 1$ , holotype USNM 151213b; 6–9, posterior, anterior, dorsal, and ventral views of the holotype from which the encrusting forms have fallen,  $\times 1$  [Neal Ranch Formation (bed 4 of P. B. King), USNM 701–1].

*Meekella enormis*, new species: 10–12, Interior, posterior, and laterally tilted views of a young brachial valve, showing the massive cardinal process,  $\times 1$ , paratype USNM 153448b [Skinner Ranch Formation (= Decie Ranch Member), USNM 705a].



PLATE 69.—*Derbyia* and *Meekella*.

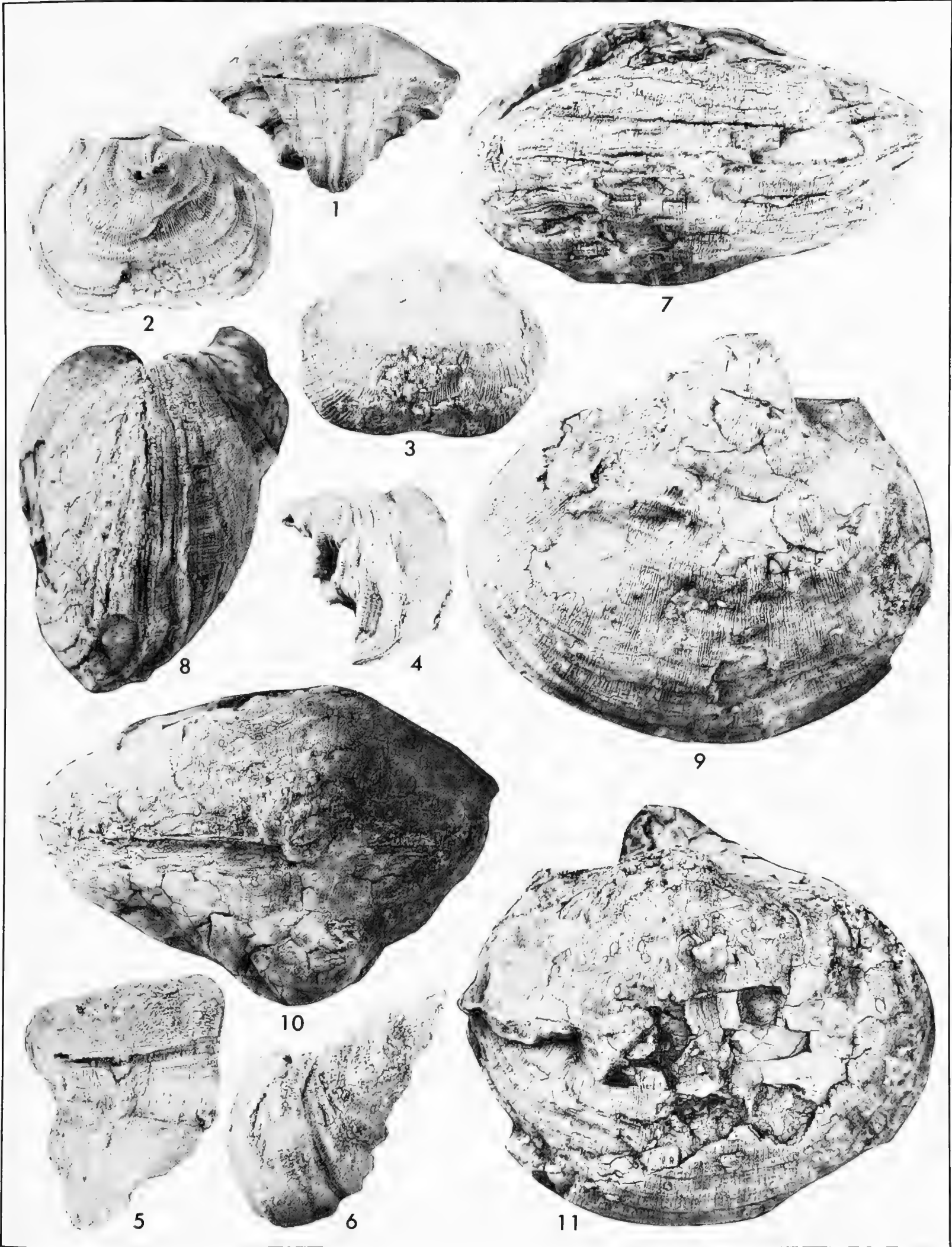


**PLATE 70***Derbyia*

*Derbyia nasuta* Girty: 1-4, Posterior, ventral, dorsal, and side views of a small individual,  $\times 1$ , hypotype USNM 151038a; 5, 6, posterior and side views of another small specimen with elongated beak,  $\times 1$ , hypotype USNM 151038c [Skinner Ranch Formation (Decie Ranch Member), USNM 707e].

7-11, Anterior, side, ventral, posterior, and dorsal views of an unusually large specimen,  $\times 1$ , hypotype USNM 151030h [Skinner Ranch Formation (Decie Ranch Member), USNM 707a].

PLATE 70.—*Derbyia*.



## PLATE 71

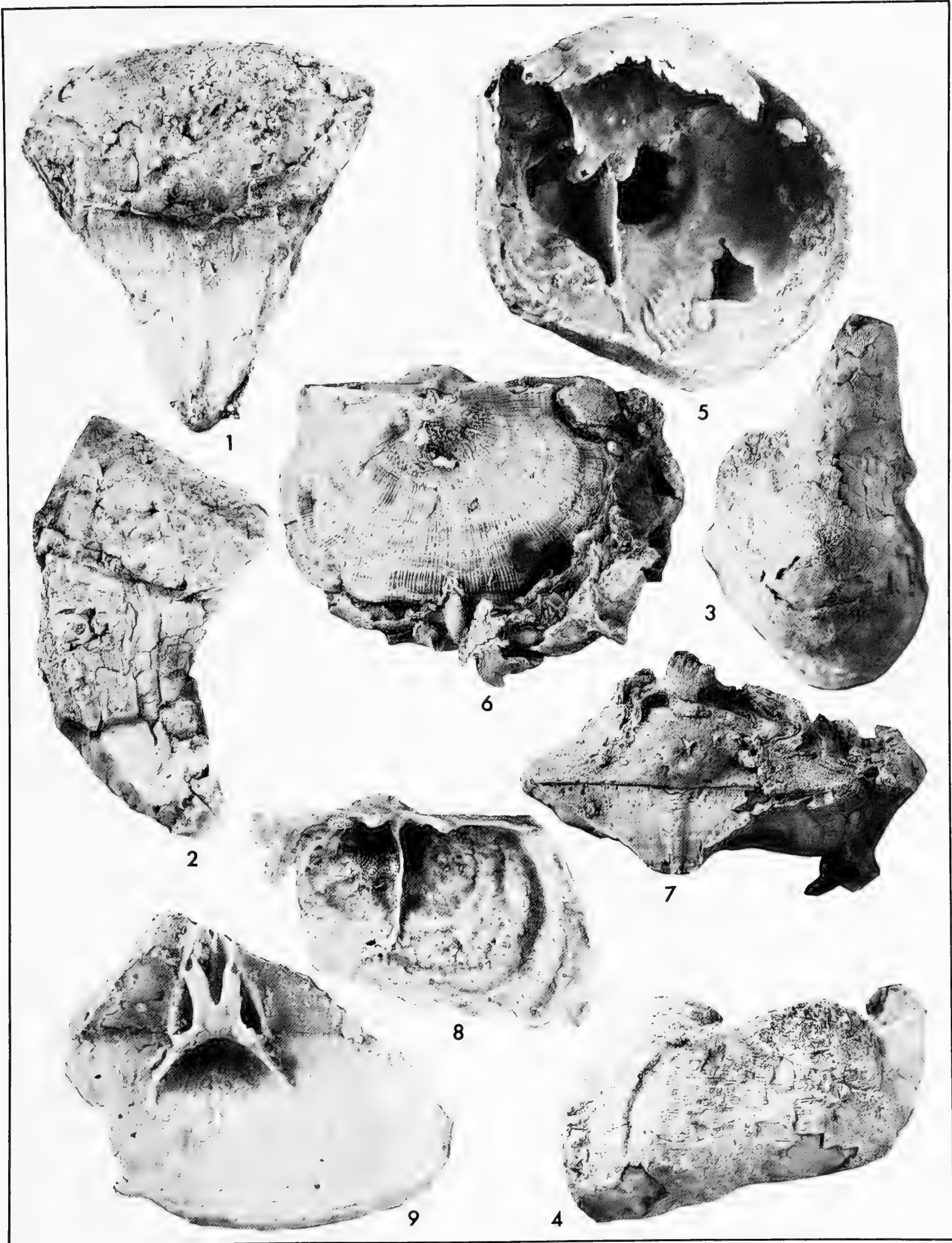
*Derbyia*

*Derbyia nasuta* Girty: 1, Large specimen with elongated beak,  $\times 1$ , hypotype USNM 151030e; 2-4, posterior, ventral, and side views of another specimen with exceptionally long beak developed because of crowded conditions, where it was cemented in life,  $\times 1$ , hypotype USNM 151030i; 5, large specimen with brachial valve removed to show cardinal process, median septum, and enormous muscle field,  $\times 1$ , hypotype USNM 151029 [Skinner Ranch Formation (Decie Ranch Member), USNM 707a].

6, 7, Ventral and posterior views of a large specimen partially encrusted by bryozoans,  $\times 1$ , hypotype USNM 153297a; 8, interior of an incomplete pedicle valve, showing long median septum,  $\times 1$ , hypotype USNM 153297b [Bone Spring Formation (lower), USNM 428e].

9, Interior of a brachial valve, showing cardinal process, and adductor field surrounded laterally by supporting plates of the cardinal process,  $\times 1$ , hypotype USNM 15103d [Skinner Ranch Formation (= Decie Ranch Member), USNM 720e].

PLATE 71.—*Derbyia*.





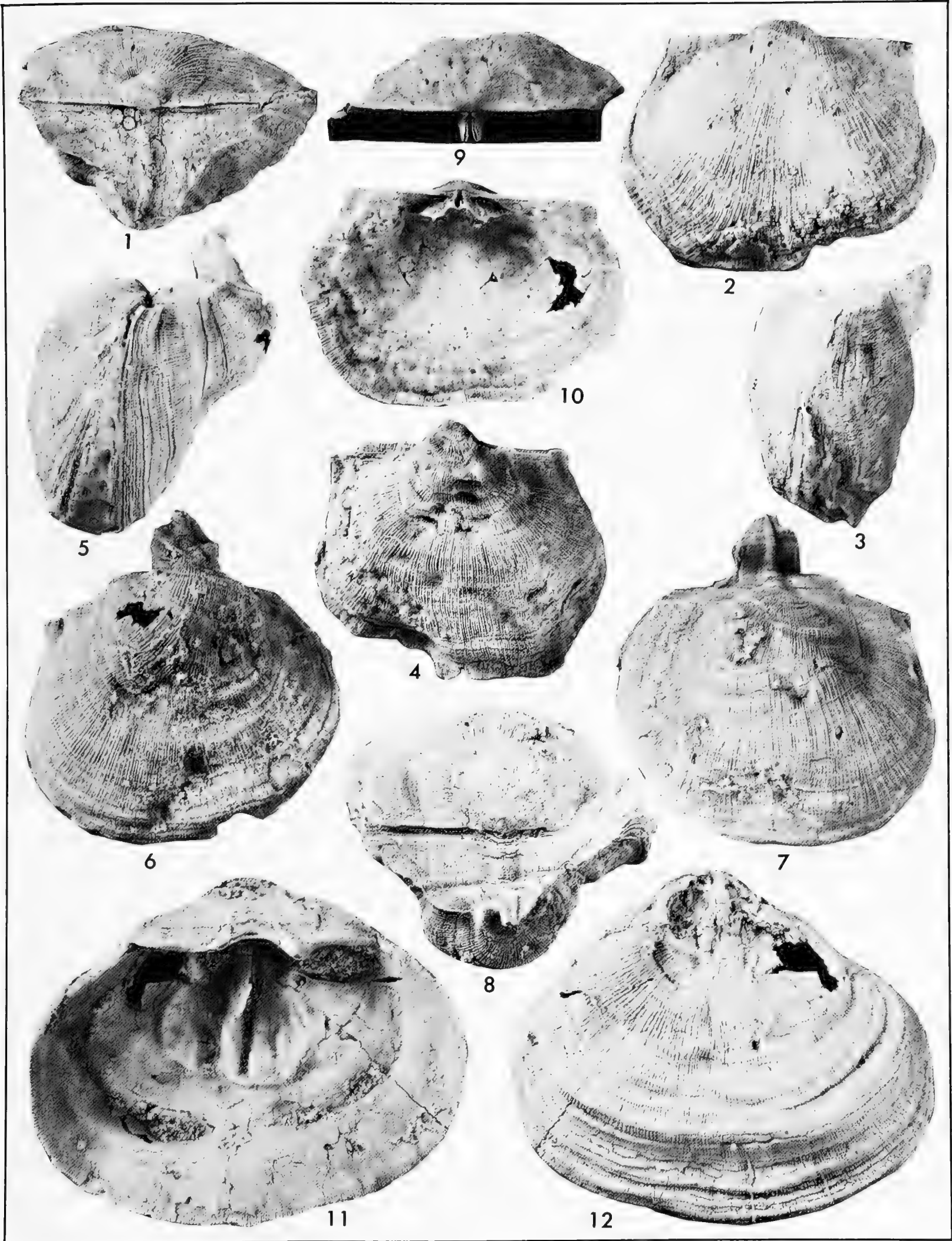
**PLATE 72***Derbyia*

*Derbyia nasuta* Girty: 1–4, Posterior, dorsal, side, and ventral views of a medium-sized specimen,  $\times 1$ , hypotype USNM 151038e; 5–8, side, ventral, dorsal, and posterior views of a fairly large specimen with narrowed and elongated beak,  $\times 1$ , hypotype USNM 151038f [Skinner Ranch Formation (= Decie Ranch Member), USNM 720e].

9, 10, Posterior and interior views of a medium-sized brachial valve,  $\times 1$ , hypotype USNM 153298 [Bone Spring Formation (lower), AMNH 625].

11, 12, Interior and exterior views of a large pedicle valve,  $\times 1$ , hypotype USNM 153299 [Bone Spring Formation (lower), USNM 725c].

PLATE 72.—*Derbyia*.



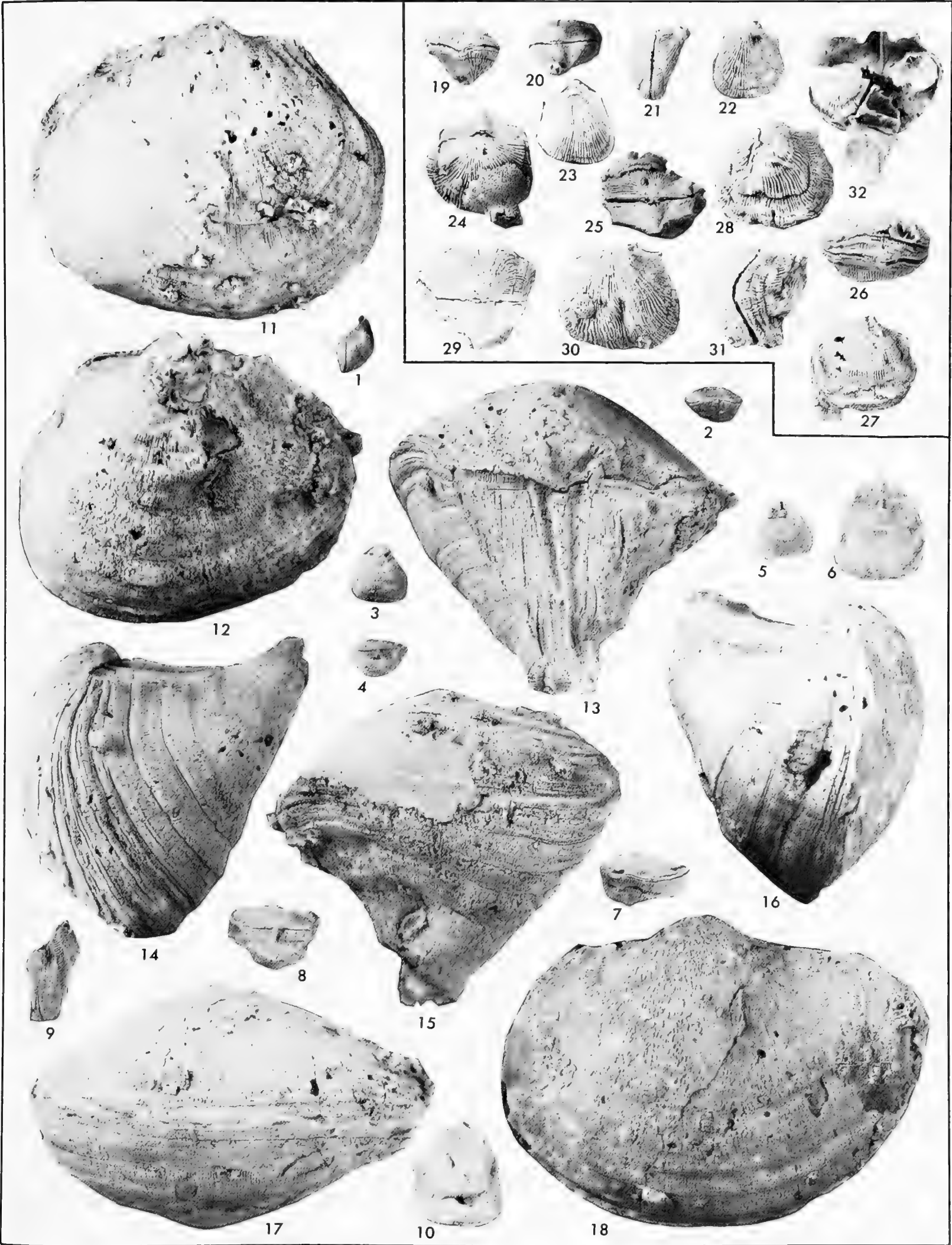
## PLATE 73

*Derbyia*

*Derbyia nasuta* Girty: 1–5, Side, anterior, ventral, posterior, and dorsal views of a very small individual,  $\times 1$ , hypotype USNM 151038i; 6–10, dorsal, anterior, posterior, side, and ventral views of a larger specimen than the preceding,  $\times 1$ , hypotype USNM 151038j; 11–15, dorsal, ventral, posterior, side, and anterior views of a medium-sized specimen,  $\times 1$ , hypotype USNM 151038g; 16–18, side, anterior, and dorsal views of a large specimen,  $\times 1$ , hypotype USNM 151038h [Skinner Ranch (= Decie Ranch Member), USNM 720e].

*Derbyia scitula*, new species: 19–23, Anterior, posterior, side, ventral, and dorsal views of a small paratype,  $\times 1$ , USNM 151202d; 24–27, dorsal, posterior, anterior, and ventral views of a larger specimen,  $\times 1$ , paratype USNM 153345; 28–31, ventral, posterior, dorsal, and side views,  $\times 1$ , holotype USNM 151202a; 32, pedicle valve with young specimens attached,  $\times 1$ , paratype USNM 151202h [Neal Ranch Formation (Bed 2 = Gray Limestone of P. B. King), USNM 701].

PLATE 73.—*Derbyia*.



## PLATE 74

*Derbyia*

*Derbyia laqueata*, new species: 1-4, Dorsal, side, posterior, and anterior views of an average specimen,  $\times 1$ , paratype USNM 153293 [Road Canyon Formation, USNM 719x].

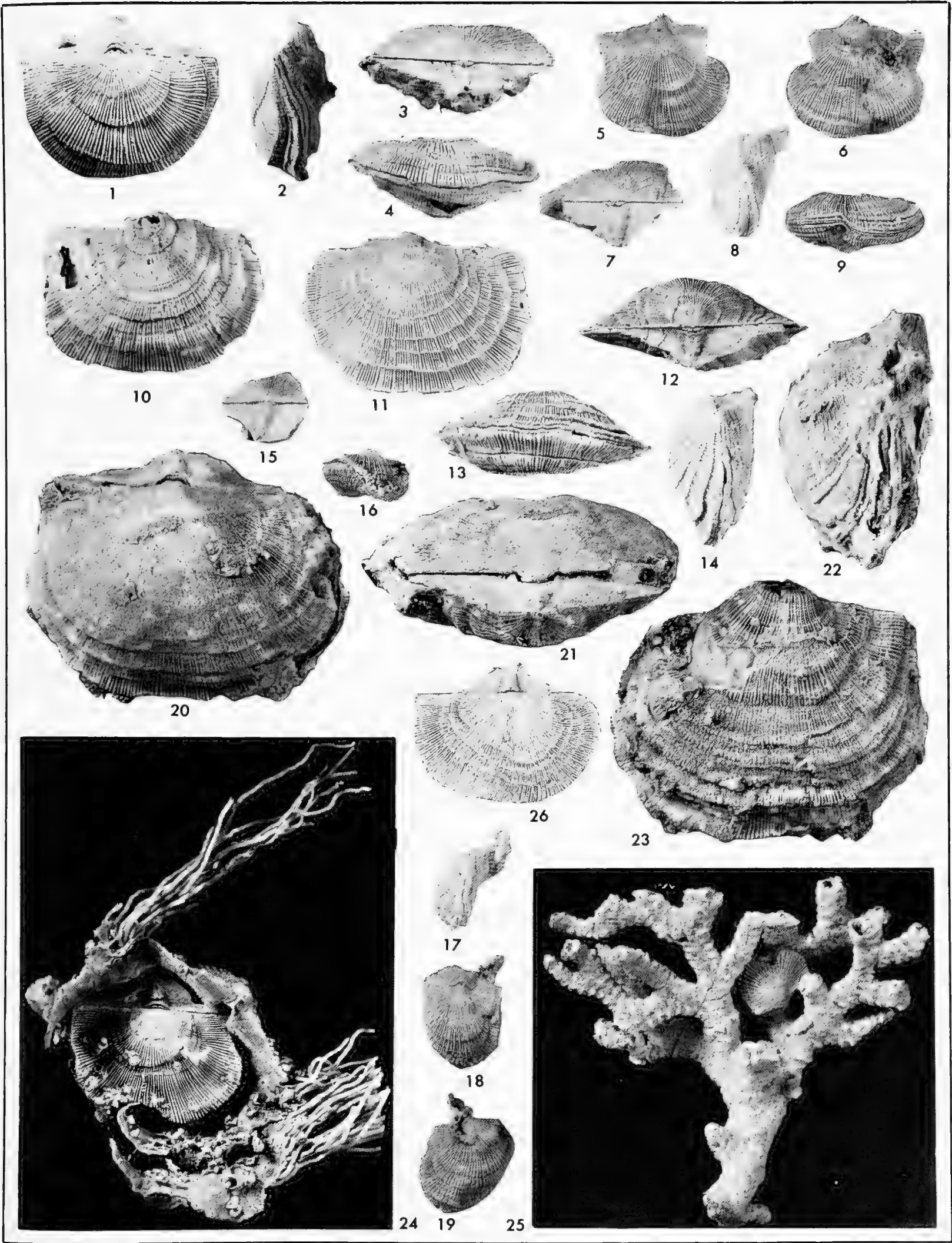
5-9, Dorsal, ventral, posterior, side, and anterior views of a small specimen,  $\times 1$ , paratype USNM 153294a; 10-14, ventral, dorsal, posterior, anterior, and side views of the holotype, USNM 151090c; 15-19, posterior, anterior, side, dorsal, and ventral views of a small, distorted specimen,  $\times 1$ , paratype USNM 153294b; 24, adult attached inside *Edriosteges*,  $\times 1$ , paratype USNM 153294c; 26, dorsal view of another complete specimen with somewhat finer ornament,  $\times 1$ , paratype USNM 153295 [Road Canyon Formation (base), USNM 703a].

20-23, Dorsal, posterior, side, and ventral views of a very large specimen,  $\times 1$ , paratype USNM 151087 [Cathedral Mountain Formation (lower), USNM 702un].

25, Small individual cemented to a branching bryozoan,  $\times 1$ , paratype USNM 153296 [Road Canyon Formation, USNM 716x].



PLATE 74.—*Derbyia*.



## PLATE 75

*Derbyia*

*Derbyia laqueata*, new species: 1-4, Anterior, posterior, dorsal, and side views of a large adult,  $\times 1$ , paratype USNM 151086a; 8, interior of a small brachial valve, showing thickened adductor field,  $\times 1$ , paratype USNM 151086b [Cathedral Mountain Formation (lower), USNM 702un].

5, 6, Full and posteriorly tilted views of the brachial valve interior, showing cardinalia,  $\times 1$ , paratype USNM 151080j; 7, posterior of the preceding, showing myophore and chilidium,  $\times 2$ ; 9, pedicle valve interior,  $\times 1$ , paratype USNM 151080k [Road Canyon Formation (base), USNM 702c].

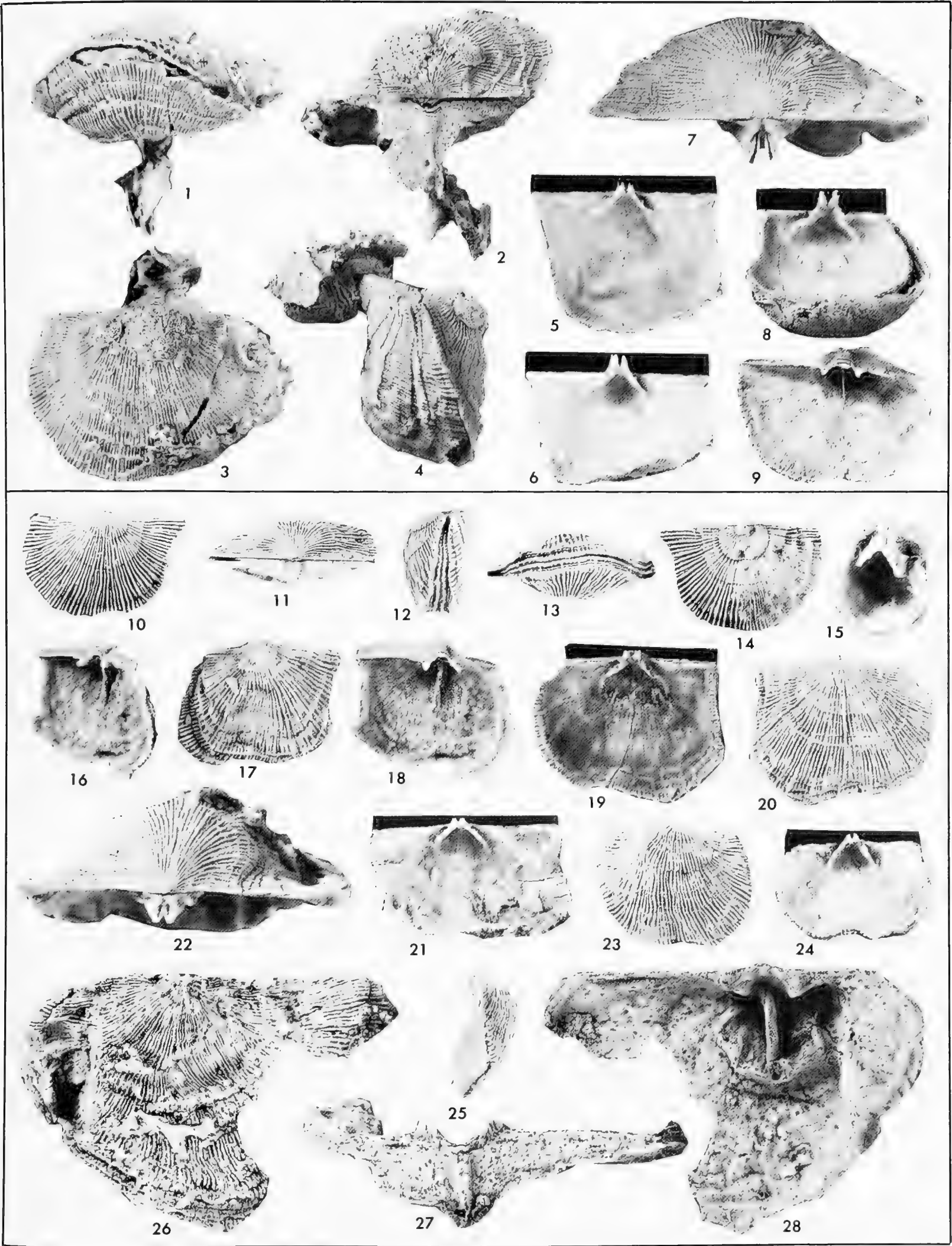
*Derbyia crenulata* Girty: 10-14, Dorsal, posterior, side, anterior, and ventral views of the holotype,  $\times 1$ , USNM 118499 [Bone Spring Formation, USGS 3764 (green)].

15, Interior of a misshapen and stunted brachial valve,  $\times 2$ , hypotype USNM 153287; 21, interior view of an average brachial valve,  $\times 1$ , hypotype USNM 151045c; 22, posterior view of preceding specimen, showing short cardinal process,  $\times 2$ ; 23-25, exterior, interior, and side views of another brachial valve,  $\times 1$ , hypotype USNM 151045d [Skinner Ranch Formation (base = Decie Ranch Member), USNM 705a].

16-18, Pedicle valve, tilted laterally, exterior and full view, showing ornament and median septum,  $\times 1$ , hypotype USNM 151047a; 19, 20, interior and exterior views of a brachial valve,  $\times 1$ , hypotype USNM 151047b [Bone Spring Formation (lower), USNM 728e].

26-28, Exterior, posterior, and interior views of a large pedicle valve,  $\times 1$ , hypotype USNM 151048 [Bone Spring Formation (lower), AMNH 625].

PLATE 75.—*Derbyia*.

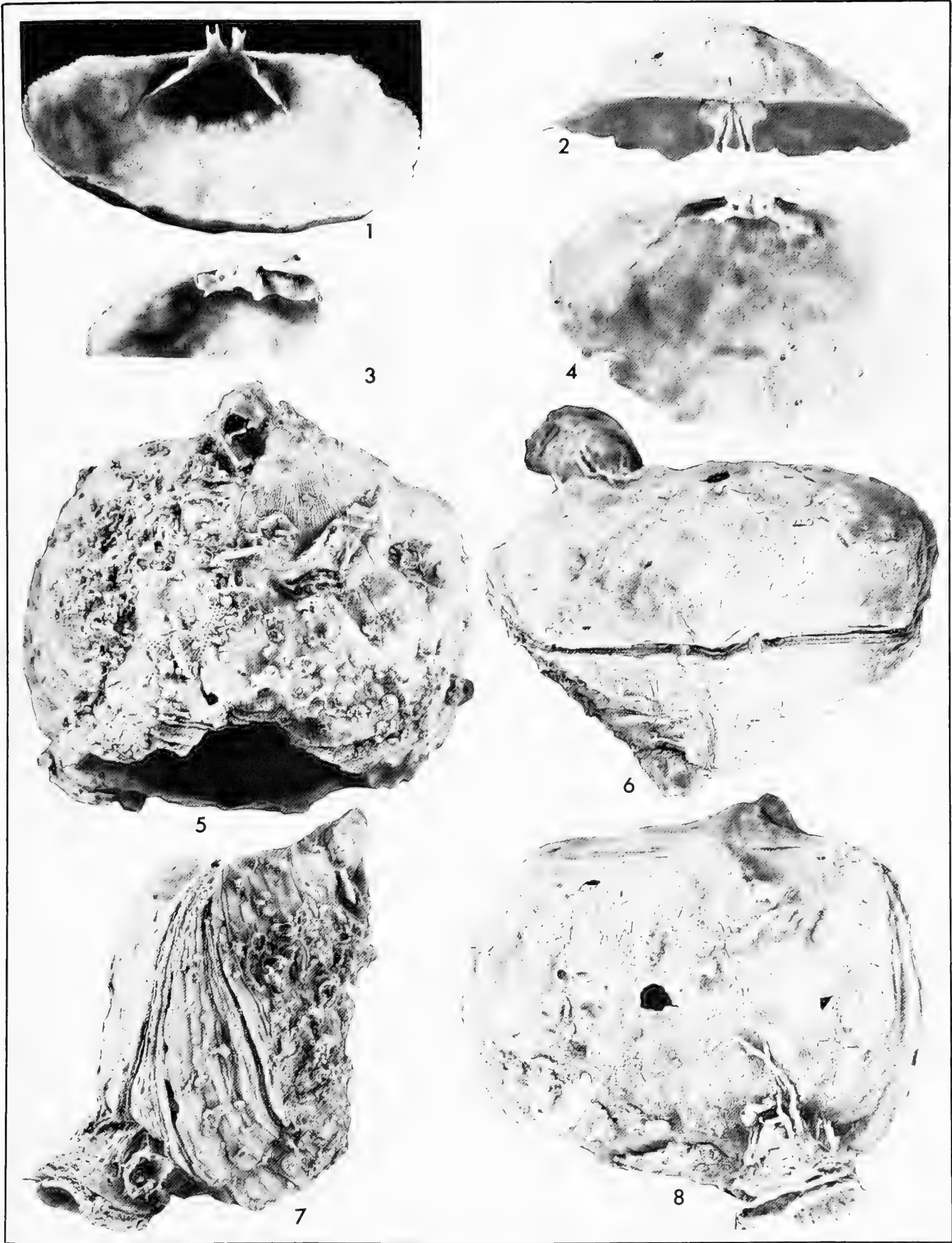


**PLATE 76***Derbyia*

*Derbyia informis*, new species: 1-4, Views of the brachial valve interior: posteriorly tilted, posterior, laterally tilted, and full, showing fairly short supporting plates and relatively small cardinal process,  $\times 1$ , paratype USNM 151055a [Cathedral Mountain Formation (lower), USNM 702].

5-8, Ventral, posterior, side, and dorsal views of a very large specimen,  $\times 1$ , holotype USNM 152606c [Road Canyon Formation (base), USNM 703a].

PLATE 76.—*Derbyia*.





## PLATE 77

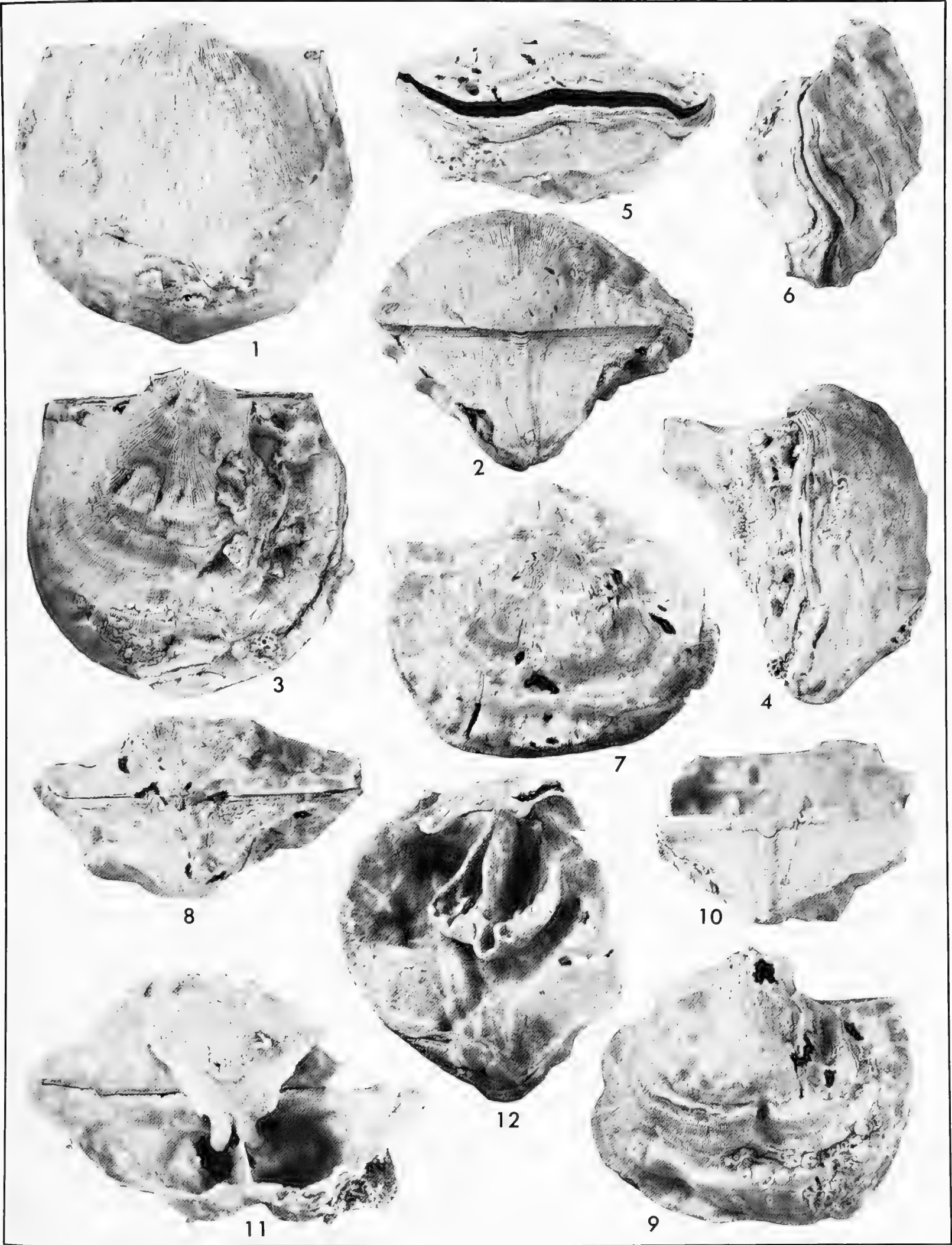
*Derbyia*

*Derbyia informis*, new species: 1–4, Dorsal, posterior, ventral, and side views of a large but narrow specimen,  $\times 1$ , paratype USNM 151056e [Cathedral Mountain Formation (lower), USNM 702].

5–9, Anterior, side, dorsal, posterior, and ventral views of a medium-sized specimen,  $\times 1$ , paratype USNM 153292 (see Plate 78 for interiors of this specimen); 12, interior view of pedicle valve tilted to the side to show the greatly thickened muscle field,  $\times 1$ , paratype USNM 151073a [Road Canyon Formation, USNM 721t].

10, Posterior view of the interarea of a large pedicle valve,  $\times 1$ , paratype USNM 153286a (see Plate 81, figures 1–3 for additional views); 11, posterior of a complete specimen showing cardinal process, supporting plates, and median septum,  $\times 1$ , paratype USNM 153286b [Road Canyon Formation (base), USNM 703a].

PLATE 77.—*Derbyia*.



## PLATE 78

*Derbyia*

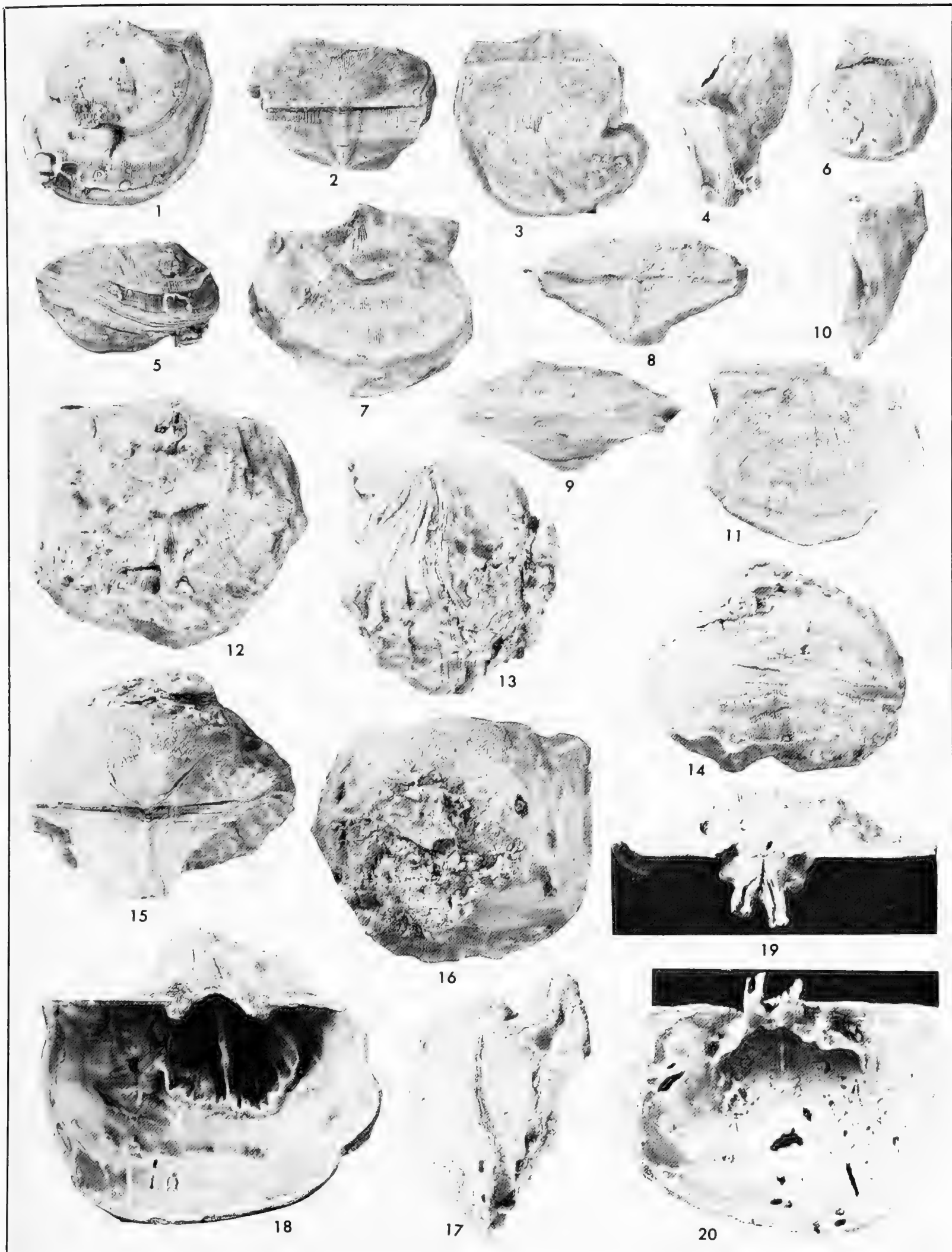
*Derbyia informis*, new species: 1-5, Ventral, posterior, dorsal, side, and anterior views of a small, compact specimen,  $\times 1$ , paratype USNM 151059d; 6, dorsal view of a small individual,  $\times 1$ , paratype USNM 151059b [Road Canyon Formation (base), locality USNM 702c].

7-11, Ventral, posterior, anterior, side, and dorsal views,  $\times 1$ , paratype USNM 152607a [Road Canyon Formation (base), locality USNM 703a].

12-16, Ventral, side, anterior, posterior, and dorsal views of a large, compact specimen,  $\times 1$ , paratype USNM 151073c; 17, side view of a medium-sized specimen, showing an elongate beak region,  $\times 1$ , paratype USNM 151055b [Cathedral Mountain (lower), locality USNM ~~702~~. 721T].

18, Interior of the pedicle valve, showing the septum and thickened muscle region,  $\times 1$ , paratype USNM 153292; 19, 20, interior and posterior views of the brachial valve of the same specimen, showing the cardinal process (see Plate 77 for exterior views of this specimen) [Road Canyon Formation, locality USNM 721t].

PLATE 78.—*Derbyia*.



## PLATE 79

*Derbyia*

*Derbyia cincinnata*, new species: 1-4, Ventral, dorsal, side, and anterior views of an immature specimen, showing development of wrinkling from a costellate stage,  $\times 1$ , paratype USNM 151136c; 5-9, side, ventral, anterior, posterior, and dorsal views of a young but strongly wrinkled specimen,  $\times 1$ , holotype USNM 151136e [Road Canyon Member (base), USNM 702c].

10-14, Side, dorsal, ventral, anterior, and posterior views of a narrow but deep specimen,  $\times 1$ , paratype USNM 153284 [Road Canyon Formation, USNM 724b].

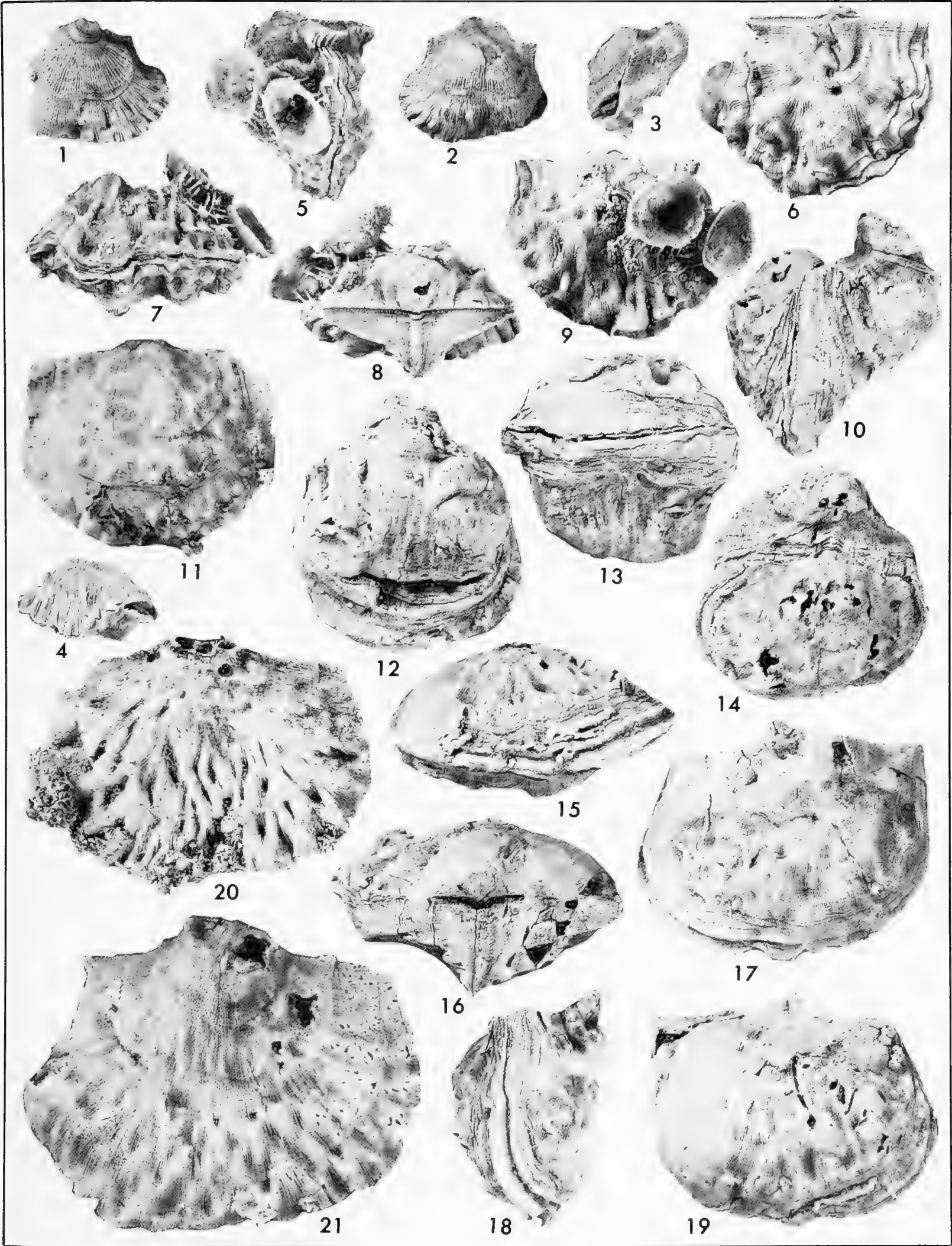
15-19, Anterior, posterior, ventral, side, and dorsal views of a medium-sized specimen,  $\times 1$ , paratype USNM 151139a [Road Canyon Formation, USNM 710u].

20, Exterior of a medium-sized pedicle valve, showing strong and irregular wrinkles,  $\times 1$ , paratype USNM 151135a [Road Canyon Formation, USNM 703d].

21, Exterior of a large and strongly wrinkled specimen,  $\times 1$ , paratype USNM 151150a [Road Canyon Formation, AMNH 503].



PLATE 79.—*Derbyia*.



## PLATE 80

*Derbyia*

*Derbyia cincinnata*, new species: 1-3, Dorsal, side, and posterior views of a large brachial valve,  $\times 1$ , paratype USNM 151141a [Road Canyon Formation (lower), USNM 719x].

4-7, Posterior, interior, posteriorly tilted, and side views of fragmentary specimen, showing cardinal process, supporting plates, and adductor myophragm,  $\times 1$ , paratype USNM 151137a [Road Canyon Formation (lower), USNM 709c].

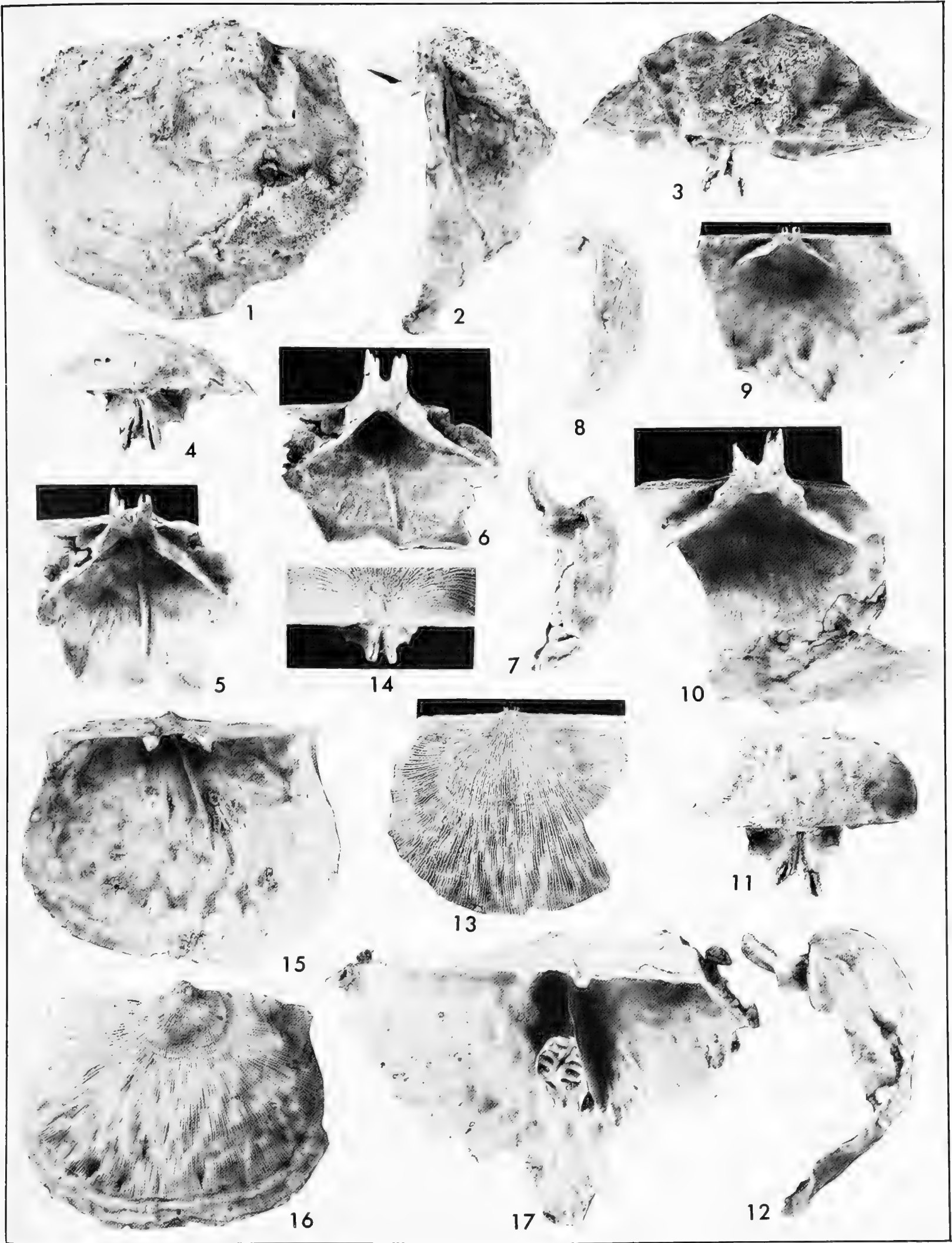
8, 9, Side and interior views of a smaller brachial valve,  $\times 1$ , paratype USNM 151131a [Road Canyon Formation (base), USNM 702c].

10-12, Interior, posterior, and side views of another fragmentary brachial valve, showing the cardinalia,  $\times 1$ , paratype USNM 151150b [Road Canyon (lower), AMNH 503].

13, 14, Exterior view,  $\times 1$ , and posterior view,  $\times 2$ , of another brachial valve, showing wrinkles and cardinal process, USNM 151134a [Road Canyon Formation (lower), USNM 703d].

15, 16, Interior and exterior views of a medium-sized pedicle valve, showing muscle scars and median septum,  $\times 1$ , paratype USNM 151143a; 17, interior of another, larger pedicle valve,  $\times 1$ , paratype USNM 151143b [Road Canyon Formation, USNM 721j].

PLATE 80.—*Derbyia*.



## PLATE 81

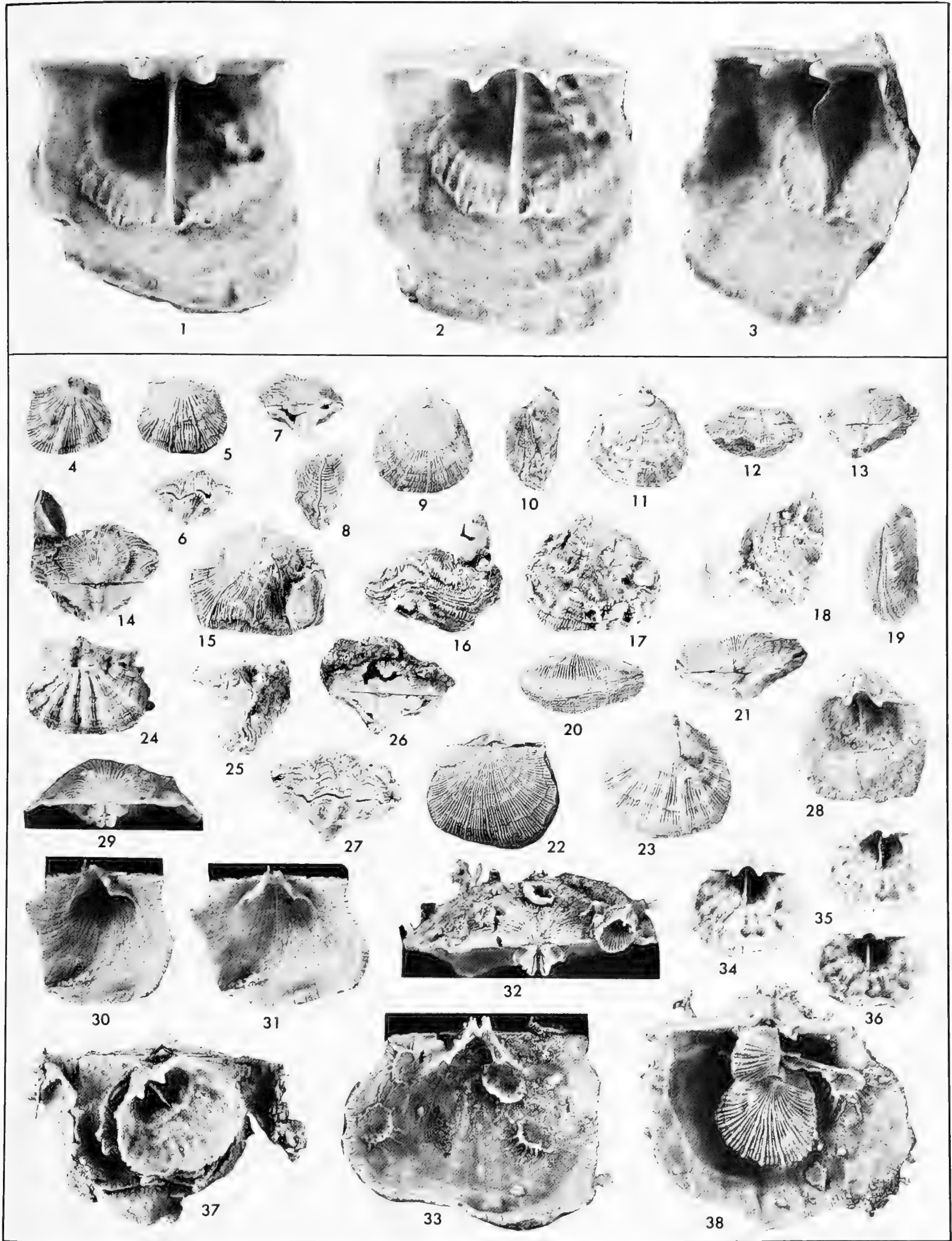
*Derbyia*

*Derbyia informis*, new species: 1-3, Views of a specimen tilted posteriorly, in full view, and tilted laterally to show thickening around the muscle scars, median septum, and its junction with the pseudodeltidium,  $\times 1$ , paratype USNM 153286a [Road Canyon Formation, locality USNM 703a].

*Derbyia complicata*, new species: 4-8, Ventral, dorsal, anterior, posterior, and side views of a small, strongly plicated paratype,  $\times 1$ , USNM 151198j; 9-13, dorsal, side ventral, anterior, and posterior views of a larger specimen,  $\times 1$ , paratype USNM 151198d; 14-18, posterior, dorsal, anterior, ventral, and side views of the holotype,  $\times 1$ , USNM 151198h; 24-27, ventral, side, posterior, and anterior views of a strongly plicated paratype,  $\times 1$ , USNM 151198i; 29-31, posterior, laterally tilted, and full views of a brachial valve, showing cardinal process and long supporting plates,  $\times 2$ , paratype USNM 151198m; 32, 33, posterior and interior views of an encrusted brachial valve,  $\times 1.5$ , paratype USNM 151198n; 34-36, full, laterally tilted, and posteriorly tilted views of a pedicle valve,  $\times 1$ , paratype USNM 151198-o; 37, pedicle valve cemented to *Institella*,  $\times 1$ , paratype USNM 151198p; 38, interior of a large pedicle valve with small individuals cemented to it,  $\times 2$ , paratype USNM 151198q [Cathedral Mountain Formation (Wedin Member), USNM 714w].

19-23, Side, anterior, posterior, dorsal, and ventral views of a fairly strongly plicated adult,  $\times 1$ , paratype USNM 151192; 28, interior of a large pedicle valve,  $\times 1$ , paratype USNM 151190a [Cathedral Mountain Formation (low), USNM 702].

PLATE 81.—*Derbyia*.





## PLATE 82

*Derbyia*

*Derbyia* cf. *D. filosa*, new species: 1, 2, Exterior and interior views of a small specimen, showing barnacle borings and the internal blisters they produce,  $\times 1$ , figured specimen USNM 153288 [Word Formation (lens between Willis Ranch and Appel Ranch Members), USNM 706b].

*Derbyia scitula*, new species: 3, Interior of a small brachial valve,  $\times 1$ , paratype USNM 153289a; 4, 5, tilted and posterior views of the same specimen, showing myophore and chilidium,  $\times 3$ ; 6, interior of another brachial valve,  $\times 1$ , paratype USNM 153289c; 7, 8, tilted and posterior views of the cardinal process of the preceding, showing one aborted prong (left) and the large chilidium,  $\times 4$ ; 9, 10, full and laterally tilted views of the pedicle valve interior,  $\times 1$ , paratype USNM 153289d [Neal Ranch Formation (bed 2 = Gray Limestone of P. B. King), USNM 701].

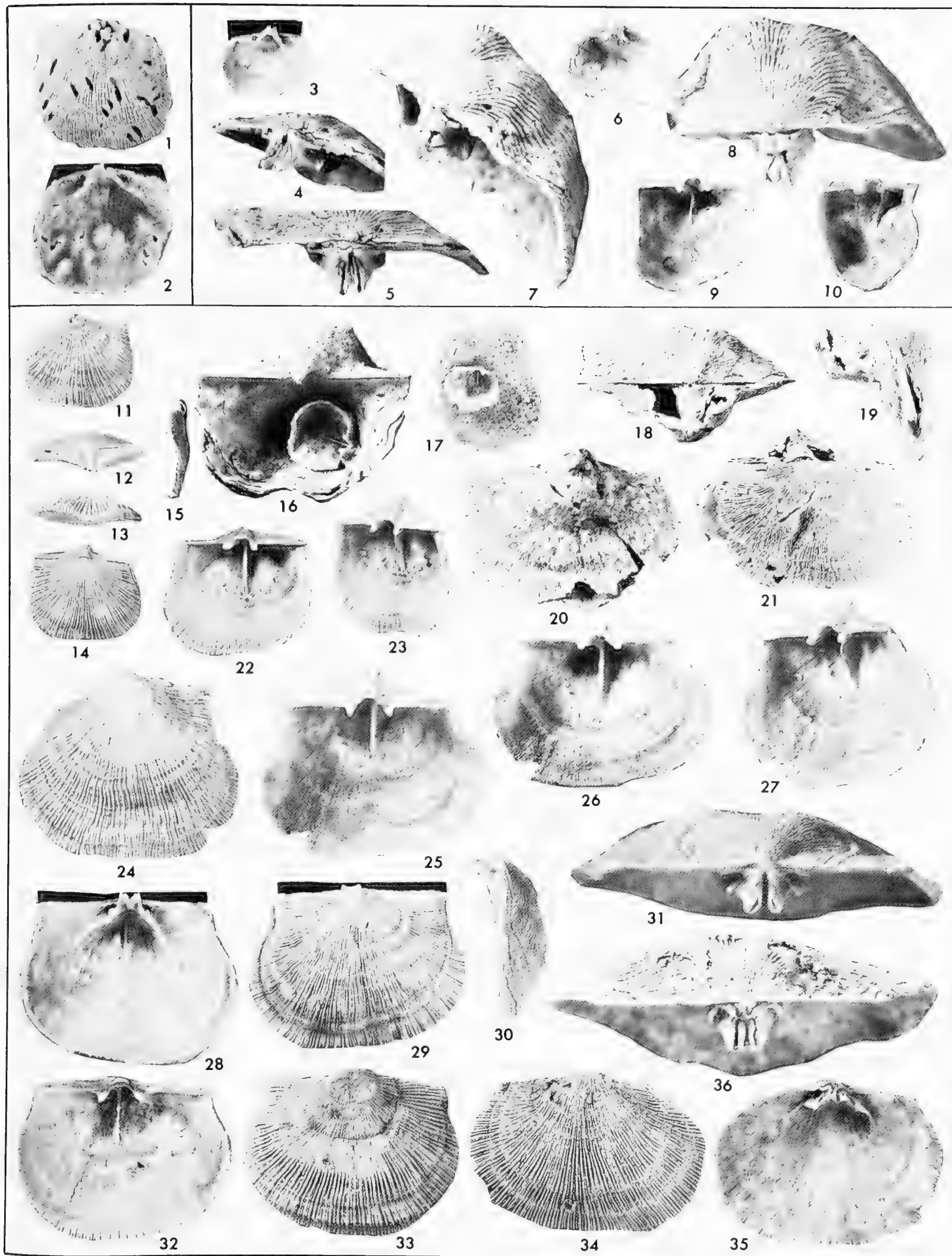
*Derbyia filosa*, new species: 11–15, Ventral, posterior, anterior, dorsal, and side views of a small specimen,  $\times 1$ , paratype USNM 151154f; 16, young specimen cemented on a brachial valve of *Paucispinifera*,  $\times 1$ , paratype USNM 151154–1; 17, another young one attached to the brachial valve of *Rhamnaria*,  $\times 1$ , paratype USNM 151154m; 22, 23, full view and laterally tilted view of a pedicle valve interior, showing delicate septum and thickened rim of the adductor field,  $\times 1$ , paratype USNM 151154–o; 28–30, interior, exterior, and side views of the brachial valve,  $\times 1$ , paratype USNM 151154j; 31, posterior view of the preceding, showing the short cardinal process,  $\times 2$  [Word Formation (lens between Willis Ranch and Appel Ranch Members), USNM 706b].

18–21, Posterior, side, ventral, and dorsal views of a complete but damaged specimen,  $\times 1$ , paratype USNM 153291 [Word Formation (Willis Ranch Member), USNM 723w].

24–27, Exterior, full, posteriorly tilted, and laterally tilted views of a large pedicle valve,  $\times 1$ , holotype USNM 153290c [Word Formation (Willis Ranch Member), USNM 706e].

32, 33, Interior and exterior views of a pedicle valve,  $\times 1$ , paratype USNM 151165a; 34, 35, exterior and interior views of a brachial valve,  $\times 1$ , paratype USNM 151165b; 36, posterior of the preceding specimen, showing cardinal process and chilidium,  $\times 2$  [Cherry Canyon Formation (Getaway Member), locality AMNH 512 = USNM 728].

PLATE 82.—*Derbyia*.



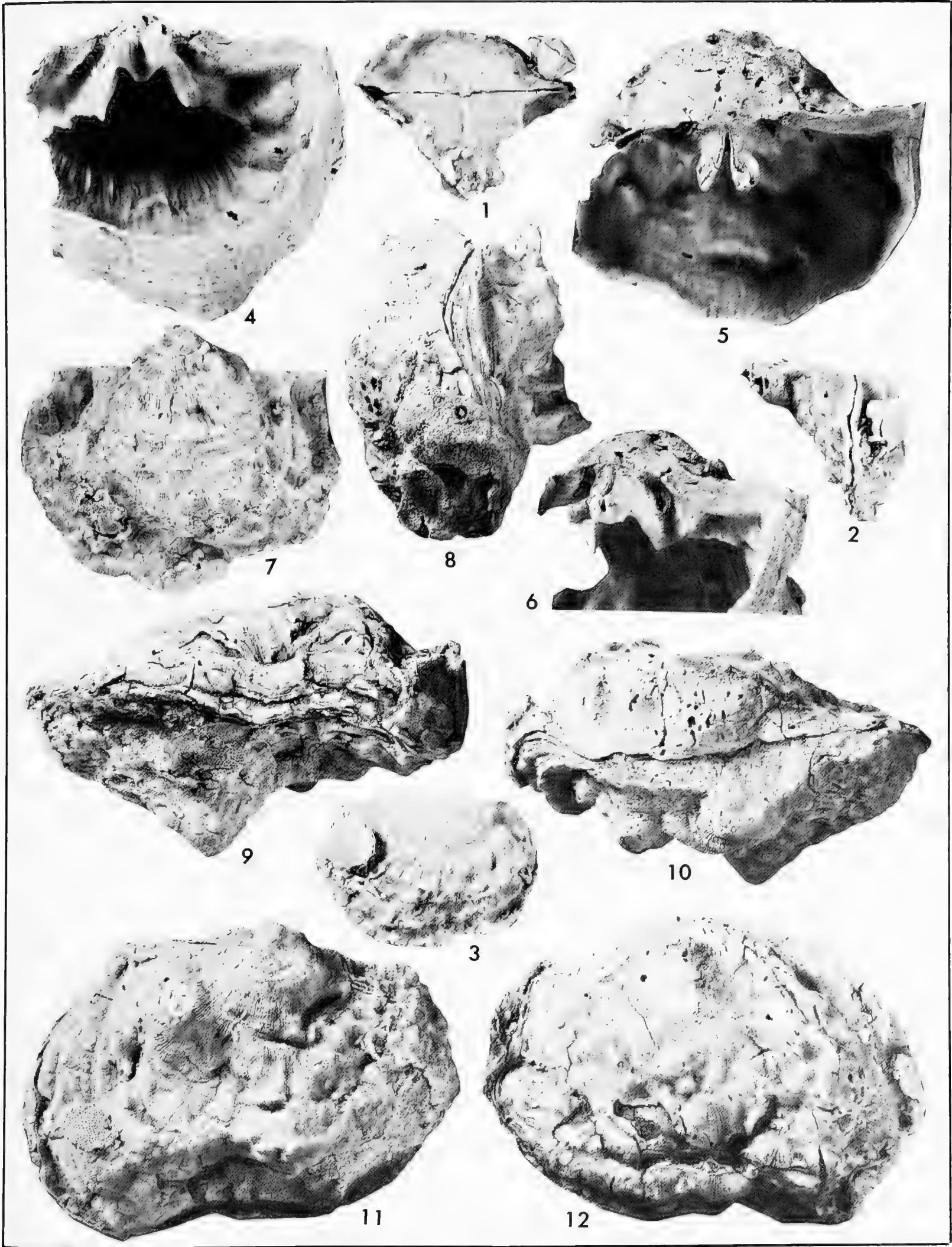
**PLATE 83***Derbyia*

*Derbyia pannucia*, new species: 1-3, Posterior, side, and dorsal views of a small specimen with an immature one attached,  $\times 1$ , paratype USNM 151115 [Word Formation (Willis Ranch Member, lower), USNM 706].

4-6, Interior, posterior, and laterally tilted views of an obese brachial valve, showing the cardinal process,  $\times 1$ , paratype USNM 151119b; 7, exterior of a medium-sized pedicle valve,  $\times 1$ , paratype USNM 151121f [Word Formation (Willis Ranch Member, upper), USNM 706e].

8-12, Side, anterior, posterior, ventral, and dorsal views of a large, much wrinkled and distorted specimen,  $\times 1$ , paratype USNM 151117 [Word Formation (lens between Willis Ranch and Appel Ranch Members), USNM 706b].

PLATE 83.—*Derbyia*.

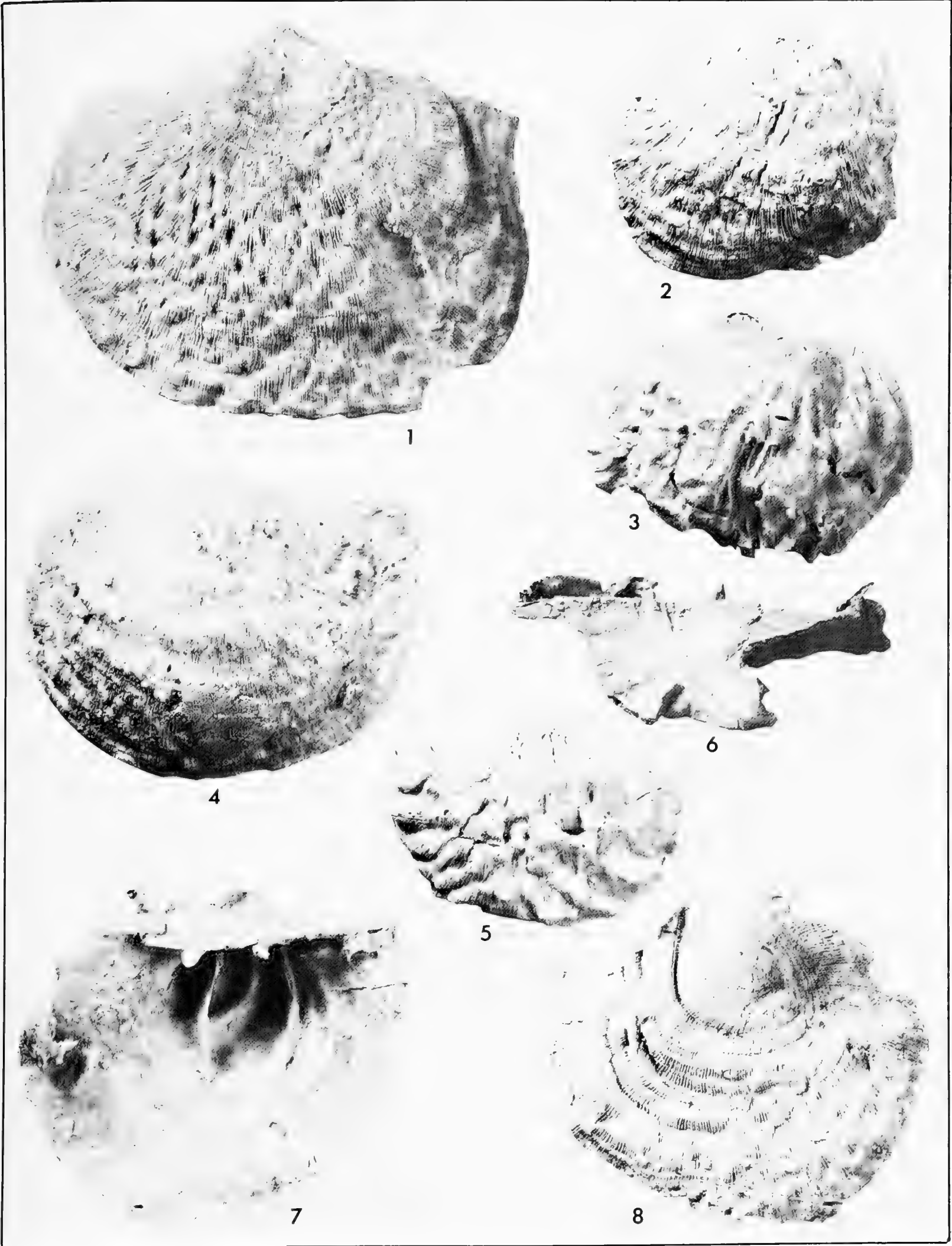


**PLATE 84***Derbyia*

*Derbyia pannucia*, new species: 1, Exterior of a large and much wrinkled pedicle valve,  $\times 1$ , paratype USNM 151122n; 2, exterior of a small brachial valve,  $\times 1$ , paratype USNM 151121a; 3, exterior of another brachial valve, showing surface irregularity,  $\times 1$ , paratype USNM 151121b; 4, a still larger brachial valve in exterior view,  $\times 1$ , paratype USNM 151121c (for interior view, see Plate 85: figure 6); 5, exterior of an intricately wrinkled brachial valve,  $\times 1$ , paratype USNM 151121d; 6–8, posterior, interior, and exterior views of a large pedicle valve,  $\times 1$ , paratype USNM 151121e [Word Formation (Willis Ranch Member, upper), USNM 706e].



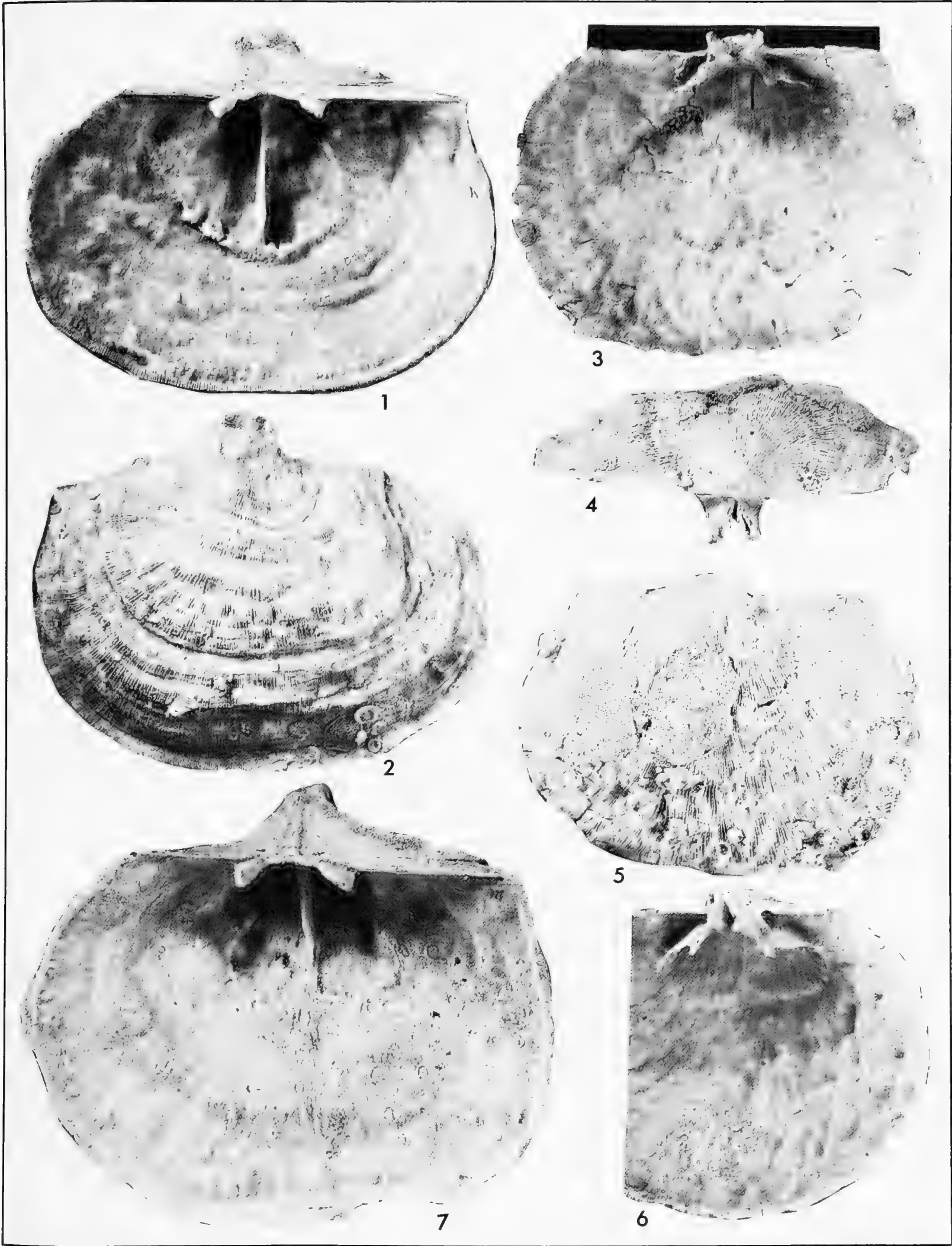
PLATE 84.—*Derbyia*.



**PLATE 85***Derbyia*

*Derbyia pannucia*, new species: 1, 2, Interior and exterior of a finely wrinkled pedicle valve, showing thickening on anterior margin of muscle scars and long septum,  $\times 1$ , paratype USNM 151122k; 3–5, interior, posterior, and exterior of a large brachial valve, showing cardinal process and wrinkles,  $\times 1$ , paratype USNM 151122p; 6, interior of another brachial valve, showing well-developed brachiophores,  $\times 1$ , paratype USNM 151121c (for exterior of this specimen, see Plate 84: figure 4); 7, interior of a very large pedicle valve,  $\times 1$ , paratype USNM 151122m [Word Formation (Willis Ranch Member, upper), USNM 706e].

PLATE 85.—*Derbyia*.



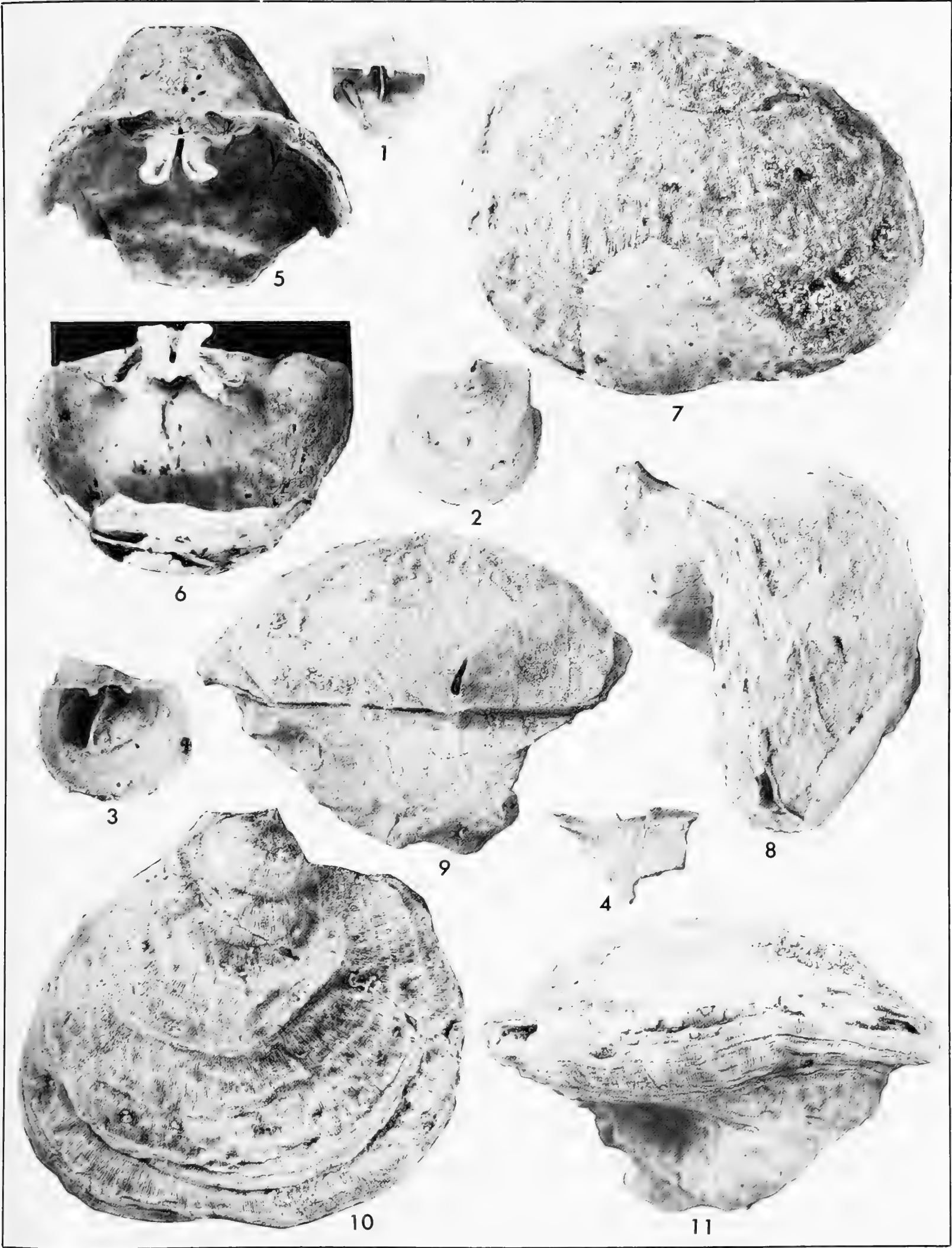
## PLATE 86

*Derbyia*

*Derbyia pannucia*, new species: 1, Interior of a small pedicle valve,  $\times 1$ , paratype USNM 151122e; 2-4, ventral, interior, and posterior views of a larger specimen,  $\times 1$ , paratype USNM 151122g; 5, 6, posterior and posteriorly tilted views of an obese brachial valve, showing the cardinal process,  $\times 1$ , paratype USNM 151122q [Word Formation (Willis Ranch Member, upper), USNM 706e].

7-11, Dorsal, side, posterior, ventral, and anterior views of a very large individual,  $\times 1$ , holotype USNM 153346 [Word Formation (lens between Willis Ranch and Appel Ranch Members), USNM 706b].

PLATE 86.—*Derbyia*.





## PLATE 87

*Derbyia*

*Derbyia texta*, new species: 1, 2, Interior and exterior views of a brachial valve, bored by barnacles and showing the blisters developed on the interior,  $\times 1$ , paratype USNM 151176 [Word Formation (lens between the Willis Ranch and Appel Ranch Members), USNM 706b].

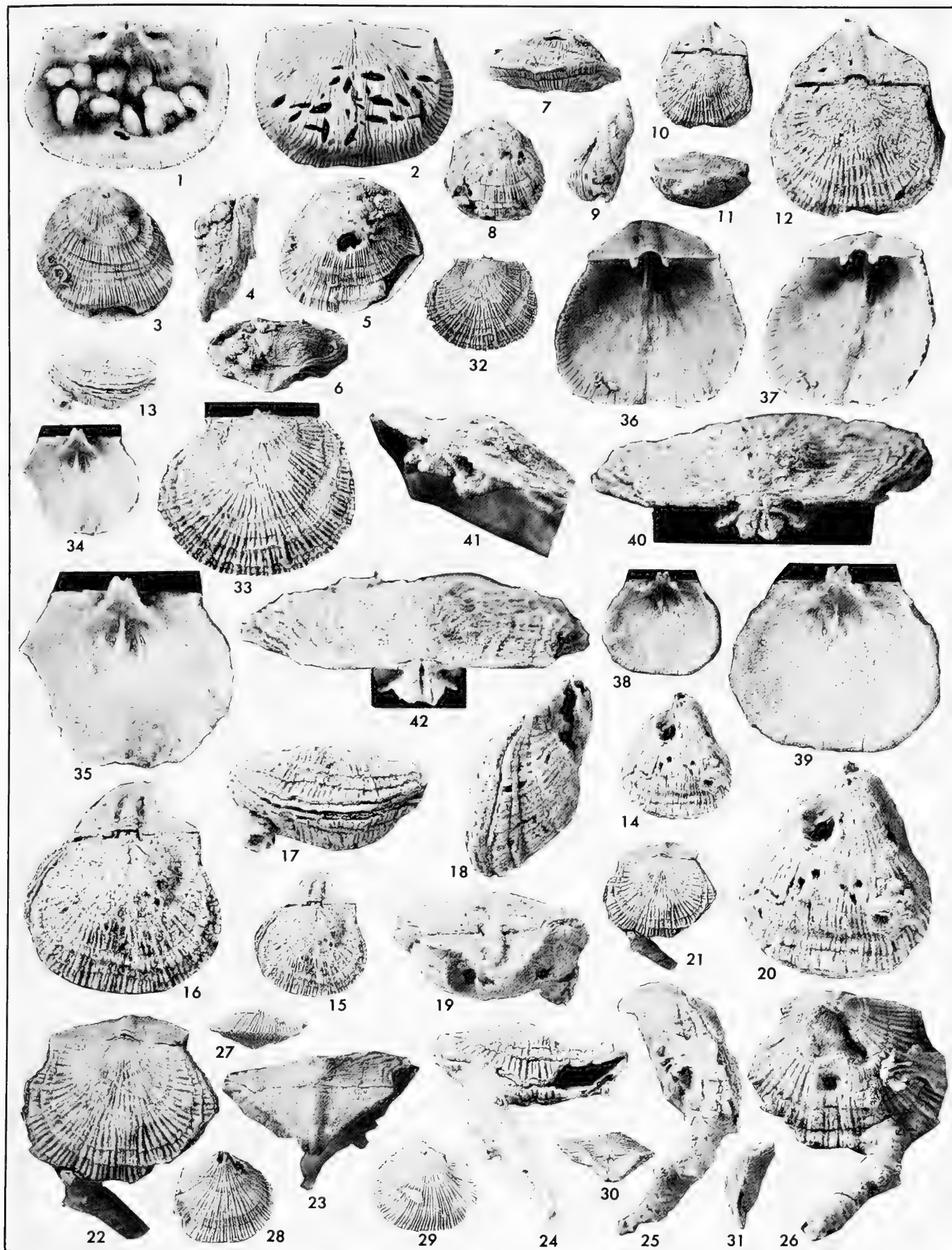
3-7, Ventral, side, dorsal, posterior, and anterior views of a fully grown specimen,  $\times 1$ , paratype USNM 151184 [Word Formation (Appel Ranch Member), USNM 715i].

8-11, Ventral, dorsal, side, and posterior views of a complete specimen,  $\times 1$ , paratype USNM 153449a; 12, dorsal view of the same specimen,  $\times 2$ ; 21, dorsal view of a complete specimen,  $\times 1$ , holotype USNM 153449b; 22-26, dorsal, posterior, anterior, side, and ventral views,  $\times 2$ , of the preceding specimen; 32, 33, exterior of a brachial valve,  $\times 1$ ,  $\times 2$ , paratype USNM 153449f; 34, 35, interior of the brachial valve and process in greater detail,  $\times 1$ ,  $\times 2$ , paratype USNM 153449e; 42, posterior of the same specimen, showing the cardinal process in greater detail,  $\times 3$ ; 36, 37, interior and laterally tilted views of a pedicle valve,  $\times 2$ , paratype USNM 153449c; 38, 39, interior of a brachial valve,  $\times 1$ ,  $\times 2$ , paratype USNM 153449d; 40, 41, same specimen in posterior and tilted views,  $\times 3$  [Word Formation (Willis Ranch Member), locality USNM 706e].

13-15, Anterior, ventral, and dorsal views of a complete specimen,  $\times 1$ , paratype USNM 151186; 16-20, dorsal, anterior, side, posterior, and ventral views of the same specimen,  $\times 2$  [Cherry Canyon Formation (Getaway Member), AMNH 600].

27-31, Anterior, ventral, dorsal, posterior, and side views of a small, complete specimen,  $\times 1$ , paratype USNM 151179e [Word Formation (China Tank Member), USNM 706c].

PLATE 87.—*Derbyia*.



## PLATE 88

*Derbyia*

*Derbyia complicata*, new species: 1, 2, Exterior and interior of a large strongly plicated pedicle valve,  $\times 1$ , paratype USNM 153450a; 3, 4, interior and exterior of fragmentary specimen, showing slits produced by boring organisms and the aberrations produced on the interior,  $\times 1$ , paratype USNM 153450c; 5, 6, exterior and interior of another small but strongly plicated pedicle valve,  $\times 1$ , paratype USNM 153450b [Cathedral Mountain Formation, locality USNM 721u].

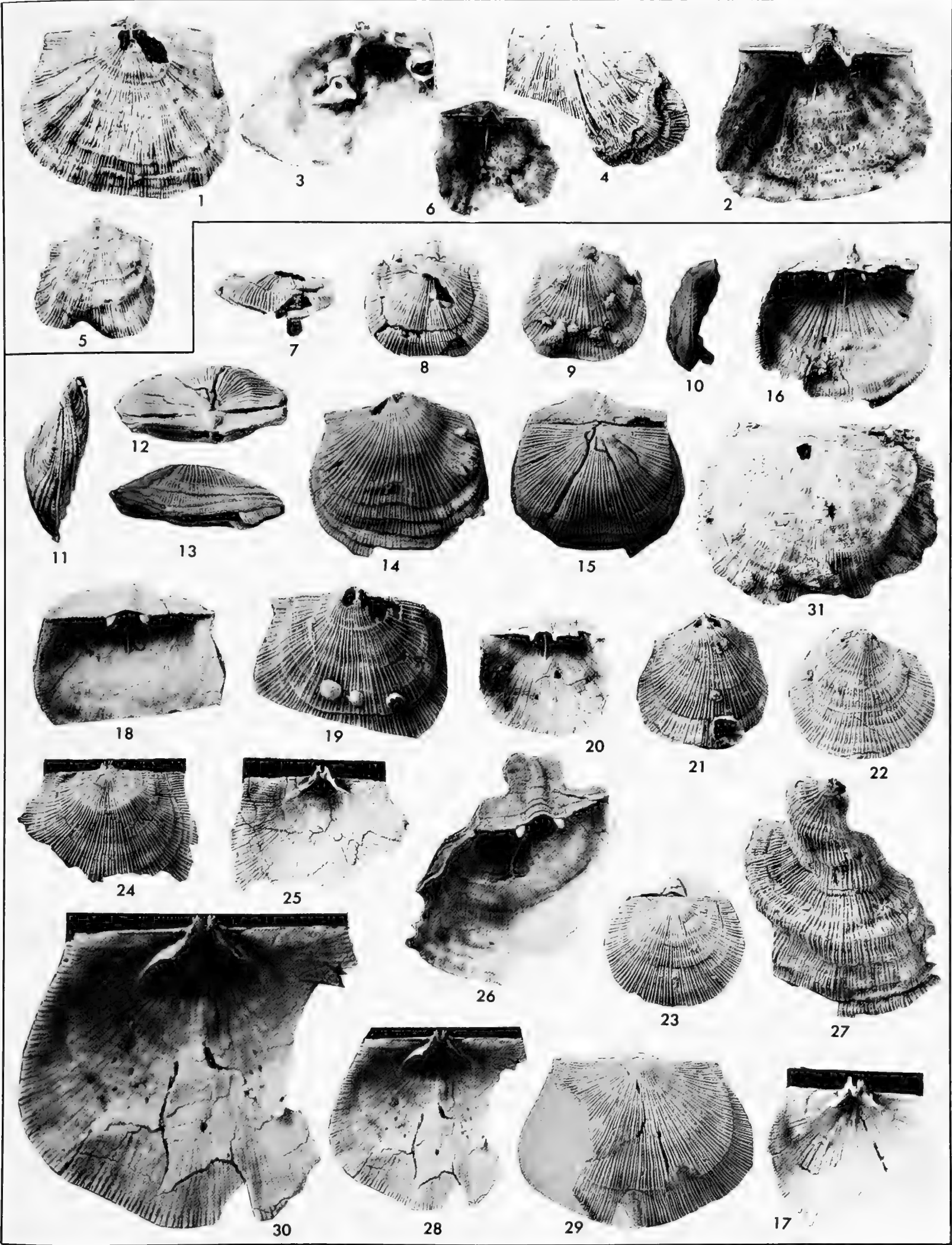
*Derbyia* species 1: 7–10, anterior, dorsal, ventral, and side views of a small individual,  $\times 1$ , figured specimen 153465a; 26, 27, interior and exterior views of an elongated specimen,  $\times 1$ , figured specimen USNM 153465b [Bell Canyon Formation (Pinery Member), AMNH 398].

11–15, Side, posterior, anterior, ventral, and dorsal views of a complete specimen,  $\times 1$ , figured specimen USNM 153466a; 16, 17, interiors of the pedicle and dorsal valves of the preceding specimen,  $\times 1$ ; 24, 25, exterior and interior of an incomplete brachial valve,  $\times 1$ , figured specimen USNM 153466b [Bell Canyon Formation (Lamar Member), USNM 728p].

18, 19, Interior and exterior of an imperfect pedicle valve,  $\times 1$ , figured specimen USNM 153467c; 20, 21, interior and exterior of a smaller pedicle valve with attached *Rigbyella*,  $\times 1$ , figured specimen USNM 153467b; 22, 23, ventral and dorsal views of a small, complete specimen,  $\times 1$ , figured specimen USNM 153467a [Bell Canyon Formation (Lamar Member), AMNH 430].

28, 29, Interior and exterior of a brachial valve,  $\times 1$ , figured specimen USNM 151205c; 30, enlargement of the previous interior view, showing flaring supporting plates and short cardinal process,  $\times 2$ ; 31, exterior of a large, much worn brachial valve,  $\times 1$ , figured specimen USNM 151205b [Bell Canyon Formation (Lamar Member), USNM 738b].

PLATE 88.—*Derbyia*.



## PLATE 89

*Geyerella, Tropidelasma, Meekella, Derbyia, Collumatus, and Teguliferina*

*Geyerella americana* Girty: 1, Posterior view of the enormous cardinal process,  $\times 1$ , hypotype USNM 153543 [Bell Canyon Formation (Lamar Member), locality USNM 728p].

*Geyerella hessi*, new species: 2, Posterior view of an imperfect pedicle valve,  $\times 1$ , figured specimen USNM 153544a; 3, 4, posterior and exterior of the brachial valve,  $\times 1$ , figured specimen USNM 153544b [Cibolo Formation (breccia bed), locality USNM 738r].

*Tropidelasma gregarium* (Girty): 5–7, Dorsal, posterior, and side views of stubby specimen,  $\times 1$ , hypotype USNM 153545a; 8–10, posterior, side, and anterior views of a more elongated specimen,  $\times 1$ , hypotype USNM 153545b [Bell Canyon Formation (Lamar Member), locality USNM 728p].

*Meekella caperata*, new species: 11–13, Anterior, posterior, and side views of an adult,  $\times 1$ , paratype USNM 153546 [Cibolo Formation (breccia bed), locality USNM 738r].

*Derbyia* cf. *D. nasuta* Girty: 14–16, Side, posterior, and interior of an elongated and narrow specimen,  $\times 1$ , figured specimen USNM 153547a; 17–19, interior, posterior and side views of a pedicle valve, showing the median septum,  $\times 1$ , figured specimen USNM 153547b; 20–22, side, posterior, and ventral views of an immature, elongated specimen,  $\times 1$ , figured specimen USNM 153547c; 23, posterior view of the same,  $\times 2$  [Cibolo Formation (breccia bed), locality USNM 738r].

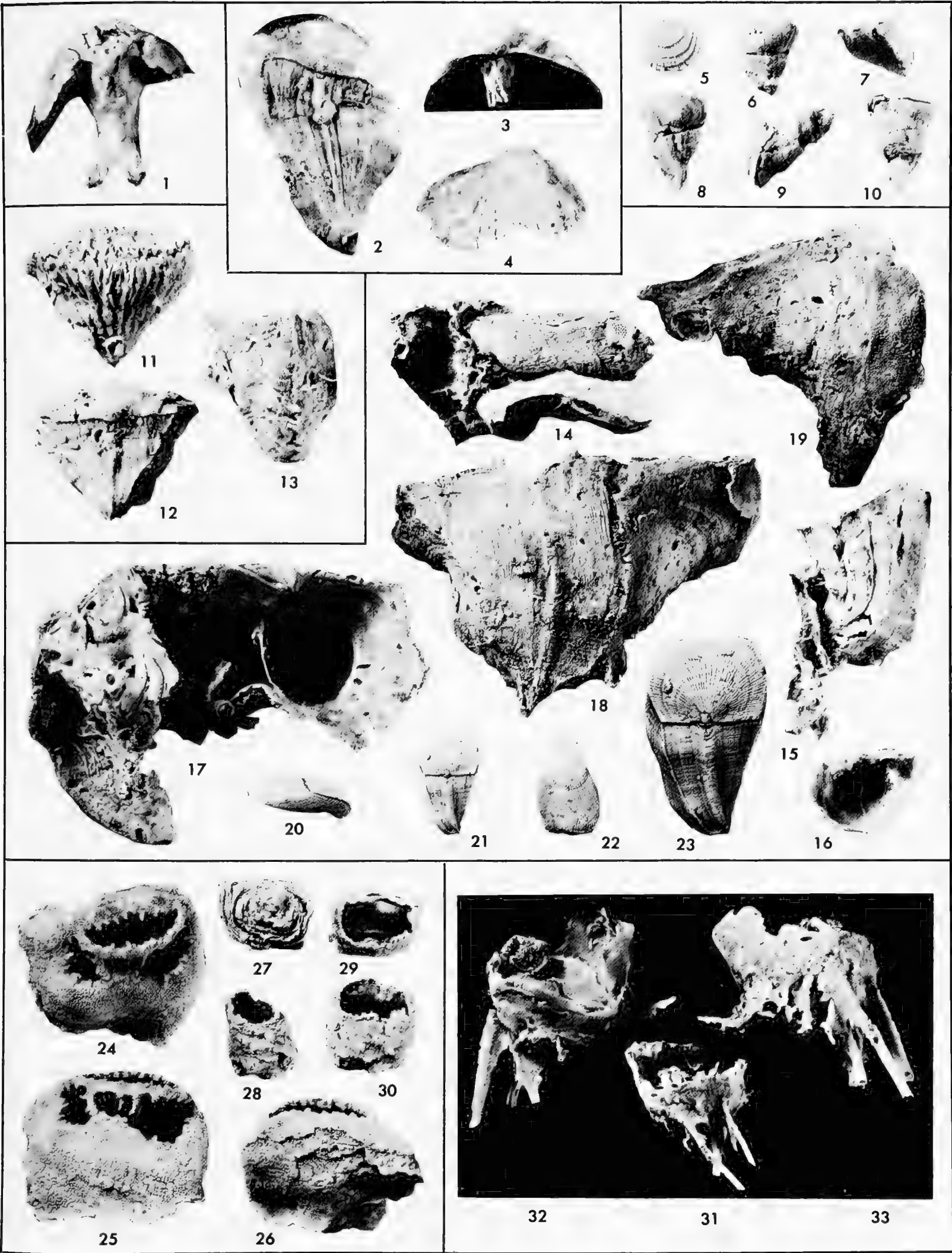
*Collumatus solitarius* Cooper and Grant: 24–26, Dorsal, anterior, and posterior views of a specimen preserving part of the covering net,  $\times 2$ , hypotype USNM 153043f [Road Canyon Formation (top), locality USNM 732j].

27–30, Ventral, side, dorsal, and anterior views of a specimen preserving the brachial valve,  $\times 1$ , hypotype USNM 153548d [Road Canyon Formation (top), locality USNM 736x].

*Teguliferina conida* (Stehli): 31, Anterior view,  $\times 1$ , hypotype USNM 153549; 32, 33, right and left side views of the same specimen, showing webs on the attachment spines,  $\times 2$  [Cibolo Formation (breccia bed), locality USNM 738r].



PLATE 89.—*Geyerella*, *Tropidelasma*, *Meekeella*, *Derbyia*, *Collumatus*, and *Teguliferina*.



## PLATE 90

*Ombonia*

*Ombonia guadalupensis* (Girty): 1-5, Ventral side, dorsal, posterior, and anterior views of a complete specimen,  $\times 1$ , lectotype USNM 118502a [Capitan Formation, locality USGS 2926 (green)].

6, 7, Exterior and interior of a pedicle valve,  $\times 1$ , hypotype USNM 151003a; 8, 9, interior and exterior of the same specimen as preceding, showing elongated spondylium,  $\times 2$ ; 25, 26, exterior and interior of a small brachial valve,  $\times 1$ , hypotype USNM 151003b; 27, 28, interior and exterior of the preceding specimen, showing cardinalia and long plates supporting the cardinal process,  $\times 2$ ; 31-33, posterior, ventral, and side views of a stout pedicle valve,  $\times 1$ , hypotype USNM 151005 [Bell Canyon Formation (Lamar Member), locality AMNH 430].

10-12, Exterior, interior, and side views of a pedicle valve,  $\times 1$ , hypotype USNM 153552a; 29, 30, interior and exterior of another, smaller pedicle valve,  $\times 1$ , hypotype USNM 153552b [Bell Canyon Formation (Lamar Member), locality AMNH L2].

13-15, Exterior, interior, and side views of a pedicle valve,  $\times 1$ , hypotype USNM 150997a [Bell Canyon Formation (Lamar Member), locality USNM 738b].

16, Interior of large brachial valve,  $\times 1$ , hypotype USNM 153478h [Bell Canyon Formation (Lamar Member), locality USNM 728p].

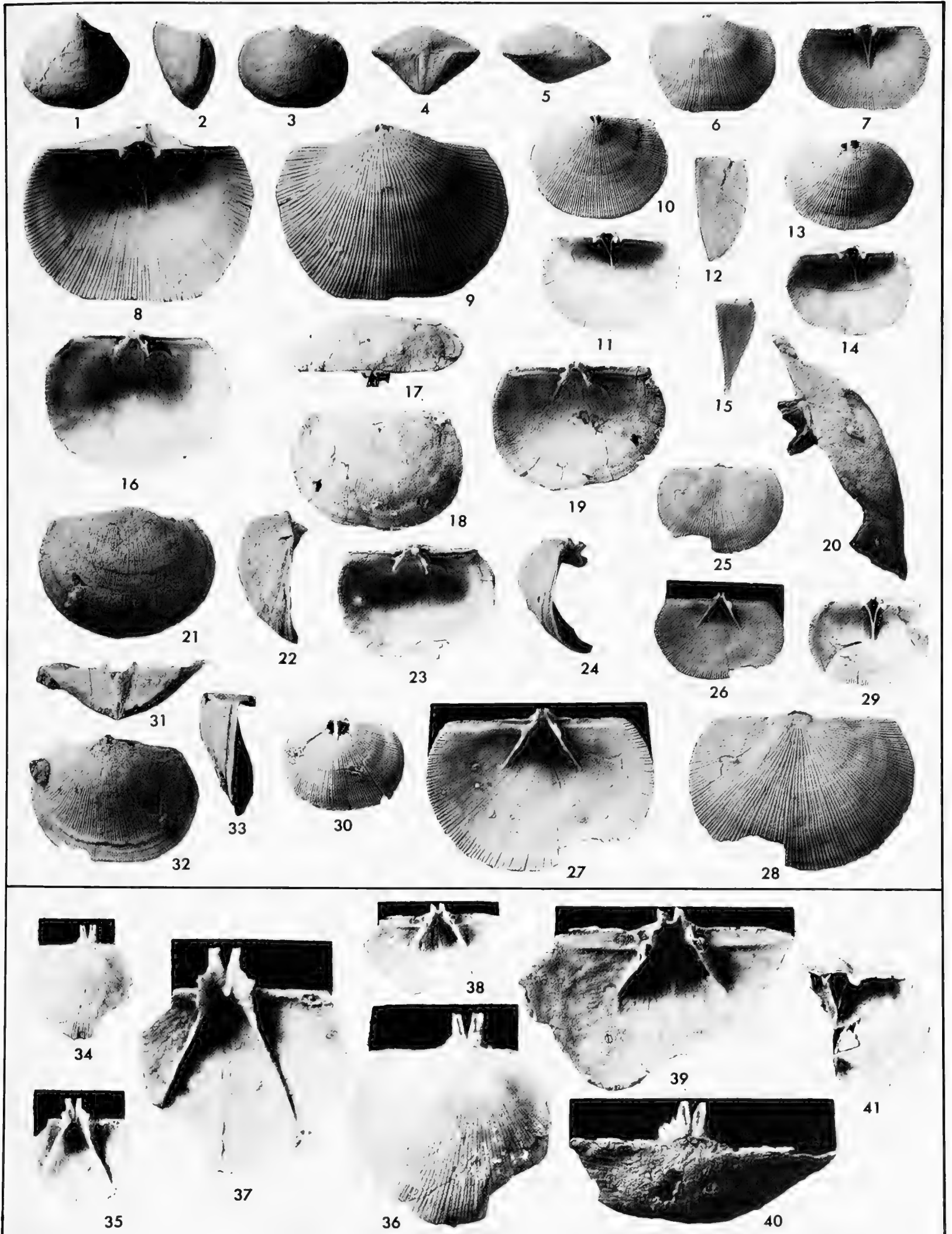
17-19, Posterior, exterior, and interior views of a large brachial valve,  $\times 1$ , hypotype USNM 150996f; 20, tilted posterior view of 17, showing cardinal process,  $\times 2$  [Bell Canyon Formation (Lamar Member), locality USNM 738].

21, 22, Exterior and side views of a stout brachial valve,  $\times 1$ , hypotype USNM 152607 [Bell Canyon Formation (Rader Member), locality AMNH 389].

23, 24, Interior and side views of a strongly convex brachial valve,  $\times 1$ , hypotype USNM 151000a [Bell Canyon Formation (Lamar Member), locality AMNH 38].

*Ombonia* species 1: 34, 35, Exterior and interior of a brachial valve  $\times 1$ , figured specimen USNM 147758a; 36, 37, same views of the preceding specimen,  $\times 2$ ; 38, interior of part of another brachial valve,  $\times 1$ , figured specimen, USNM 147758b; 39, 40, interior and posterior of the preceding specimen, showing the cardinal process,  $\times 2$ ; 41, interior of the pedicle valve, showing the spondylium,  $\times 1$ , figured specimen, USNM 147758c [Cherry Canyon Formation (Getaway Member), locality USNM 732].

PLATE 90.—*Ombonia*.



## PLATE 91

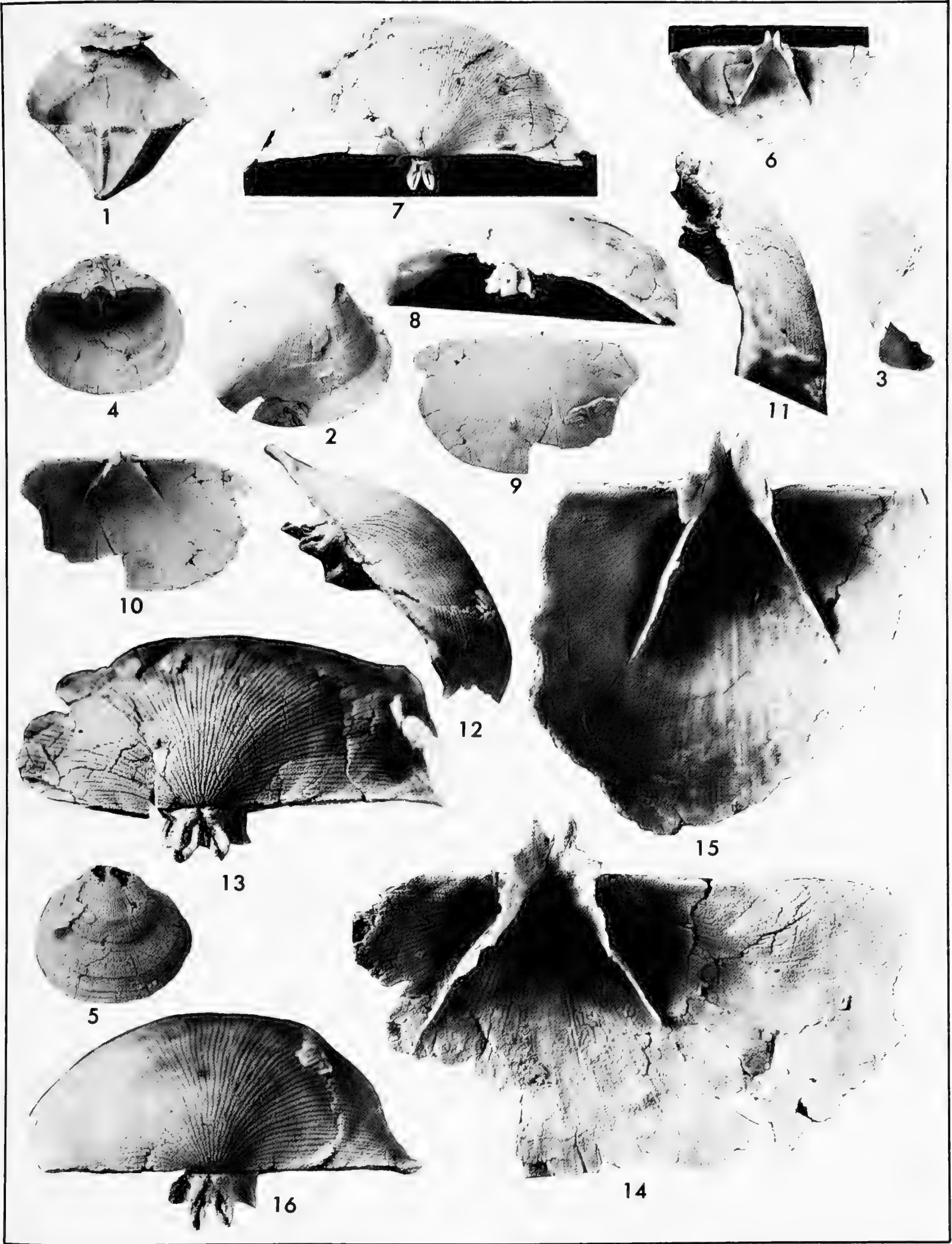
*Ombonia*

*Ombonia guadalupensis* (Girty): 1-3, Posterior, exterior, and side views of a medium-sized pedicle valve,  $\times$  1, hypotype USNM 153478a; 6, interior of the dorsal valve, showing the elongated supporting plates to the cardinal process,  $\times$  1, hypotype USNM 153478b; 7, 8, posterior and partial side views of the same specimen, showing the short cardinal process,  $\times$  2; 11-14, side, partial side, posterior views,  $\times$  2, and interior view,  $\times$  3, showing the myophore, long supporting plates (erismata), and stubby cardinal process, hypotype USNM 153478c; 15, 16, posterior and interior of another fragmentary dorsal valve, showing the cardinalia,  $\times$  3, hypotype USNM 153478d [Bell Canyon Formation (Lamar Member), locality USNM 728p].

4, 5, Interior and exterior of a small pedicle valve,  $\times$  1, hypotype USNM 150996a [Bell Canyon Formation (Lamar Member), locality USNM 738].

9, 10, Exterior and interior of a large brachial valve,  $\times$  1, hypotype USNM 150997-1 [Bell Canyon Formation (Lamar Member), locality USNM 738b].

PLATE 91.—*Ombonia*.





## PLATE 92

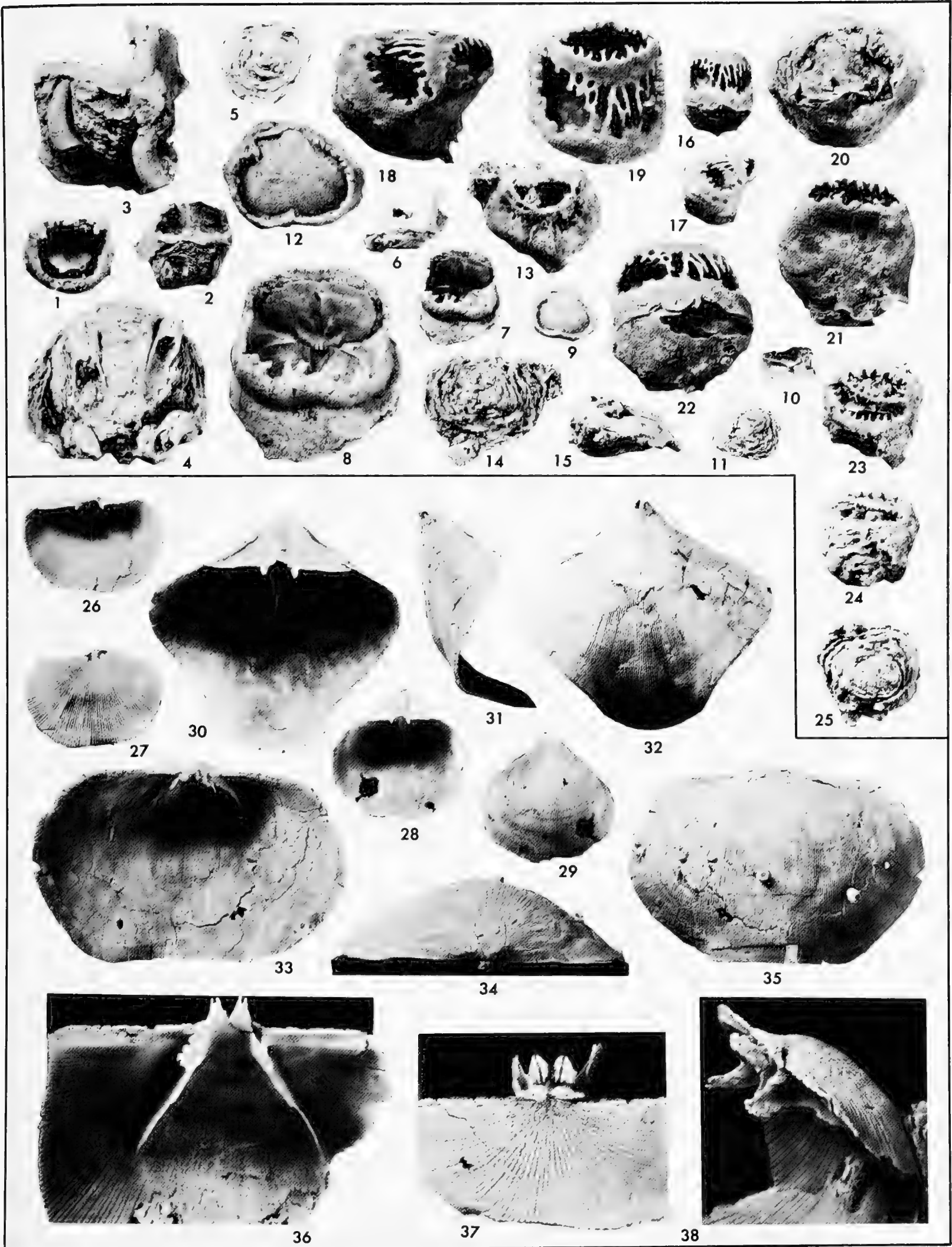
*Collumatus* and *Ombonia*

*Collumatus solitarius* Cooper and Grant: 1, 2, Dorsal and anterior views,  $\times 1$ , paratype USNM 153043g; 3, 4, side and ventral views of the same specimen, showing remnants of large pelecypod spines between and to which the specimen was attached in life,  $\times 2$  [Road Canyon Formation (top), locality USNM 732j].

5-7, Ventral, side, and dorsal views,  $\times 1$ , paratype USNM 153548f; 8, dorsal view of the preceding and showing the dorsal valve with its small cardinal process,  $\times 2$ ; 9-11, dorsal, side, and ventral views of a very young specimen with dorsal valve in place,  $\times 1$ , paratype USNM 153548c; 12, the preceding specimen;  $\times 2$ ; 13-15, dorsal, ventral, and side views of a flattened specimen,  $\times 1$ , paratype USNM 153548g; 16-17, dorsal and side views of a small specimen preserving part of the calcareous coscinidium,  $\times 1$ , holotype USNM 153548a; 18-22, side, posterior, ventral, anterior, and posterior views of the holotype,  $\times 2$ ; 23-25, dorsal, side, and ventral views of another paratype,  $\times 1$ , USNM 153548b [Road Canyon Formation (top), locality USNM 736x].

*Ombonia guadalupensis* (Girty): 26, 27, Interior and exterior of a small, wide pedicle valve,  $\times 1$ , hypotype USNM 153478e; 28, 29, interior and exterior of another small pedicle valve,  $\times 1$ , hypotype USNM 153478f; 30-32, interior, side, and exterior views of a very large pedicle valve,  $\times 1$ , hypotype USNM 153478g; 33-35, interior, posterior, and exterior views of an unusually large brachial valve,  $\times 1$ , hypotype USNM 153478h; 36-38, interior, posterior, and partial side views of a brachial valve interior, showing the cardinalia,  $\times 3$ , hypotype USNM 153478i [Bell Canyon Formation (Lamar Member), locality USNM 728p].

PLATE 92.—*Collumatus* and *Ombonia*.



## PLATE 93

*Goniarina*, *Orthotetella*, and *Diplanus*

*Goniarina* species 2: 1, 2, Exterior and interior of a small brachial valve,  $\times 4$ , figured specimen USNM 150421a [Cathedral Mountain Formation (lower), locality USNM 702b].

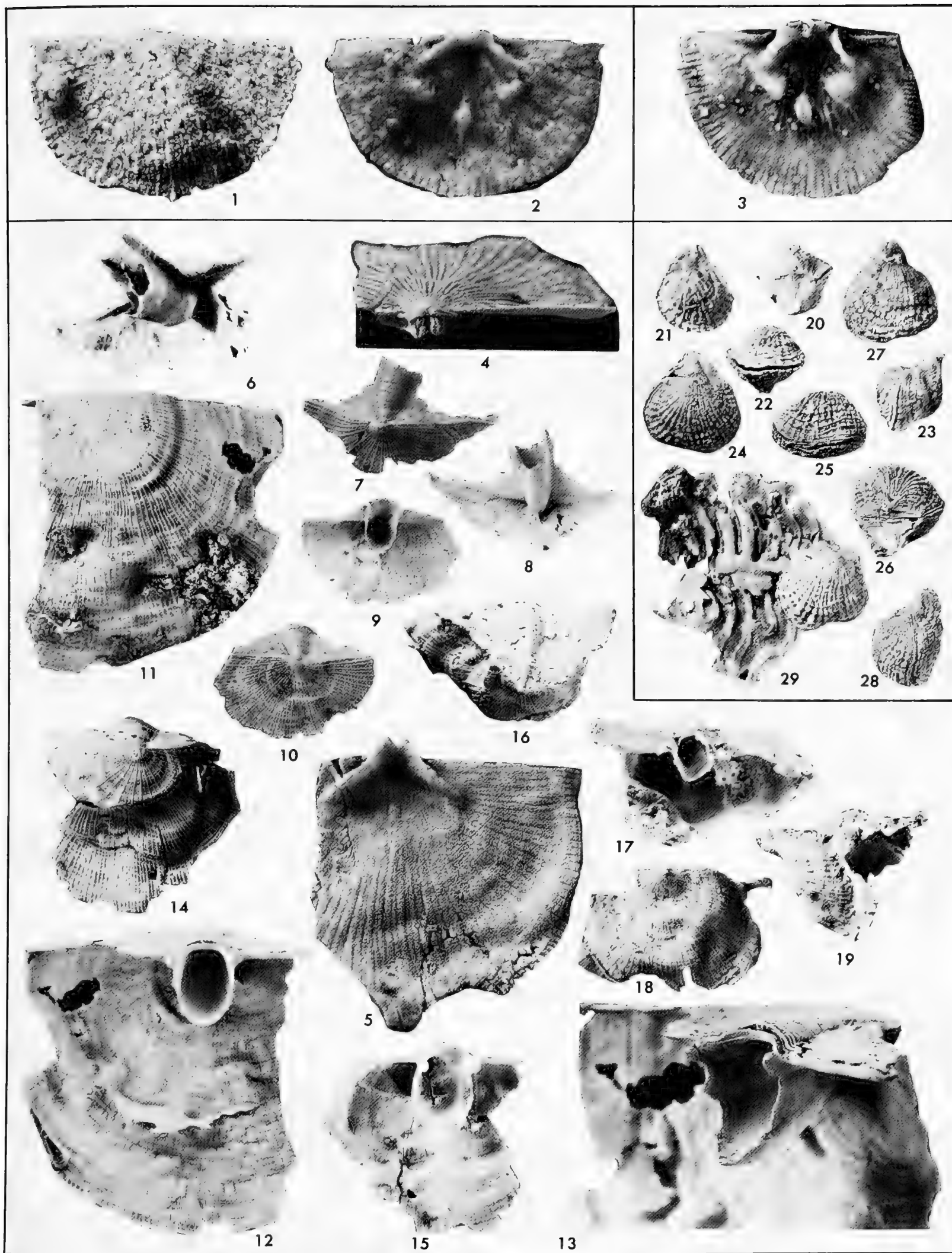
*Goniarina* species 7: 3, Interior of a brachial valve with thickened cardinalia, bulbous median ridge, and lateral swellings,  $\times 4$ , figured specimen USNM 153511a [Cathedral Mountain Formation, locality USNM 726x].

*Orthotetella wolfcampensis* R. E. King: 4, 5, Posterior and interior of the brachial valve, showing cardinalia with long supporting plates,  $\times 4$ , paratype USNM 151218b; 6–8, laterally tilted,  $\times 1.5$ , posterior, and anterior views,  $\times 1$ , of a small pedicle valve, showing the long tubular spondylium and septum, paratype USNM 151218a; 9, 10, interior and exterior views of another pedicle valve,  $\times 1$ , paratype USNM 151218d [Neal Ranch Formation, locality USNM 701k].

11, 12, Exterior and interior of a large pedicle valve, showing tubular spondylium,  $\times 1$ , paratype USNM 151214d; 13, the same specimen in partial side view,  $\times 2$ ; 14, 15, exterior and interior of a medium-sized pedicle valve,  $\times 1$ , paratype USNM 151214a; 16–19, posterior, interior, ventral, and side views of another pedicle valve,  $\times 1$ , paratype USNM 151214e [Neal Ranch Formation (bed 2 = Gray Limestone of P. B. King), locality USNM 701].

*Diplanus* cf. *D. rarus*, new species: 20–23, Posterior, dorsal, anterior, and side views of a complete specimen,  $\times 1$ , figured specimen USNM 153512a; 24–28, dorsal, anterior, posterior, ventral, and side views of a larger specimen,  $\times 1$ , figured specimen USNM 153512b; 29, large specimen attached to *Eolyttonia*,  $\times 1$ , figured specimen USNM 153512c [Cibolo Formation (breccia bed), locality USNM 728–1].

PLATE 93.—*Goniarina*, *Orthotetella*, and *Diplanus*.



## PLATE 94

*Orthotetella* and *Goniarina*

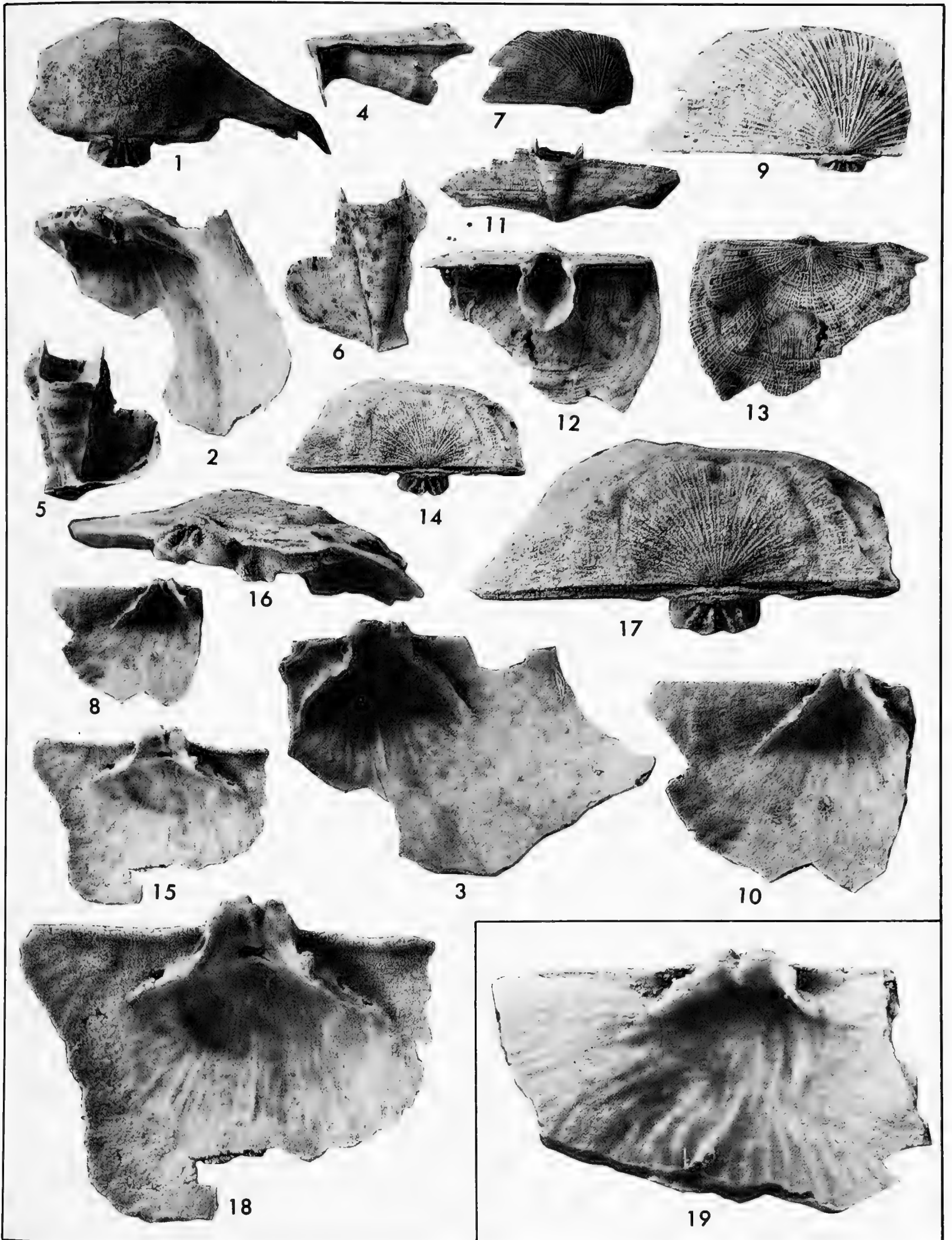
*Orthotetella wolfcampensis* R. E. King: 1-3, Posterior, partial side and interior views of a large fragmentary brachial valve, showing cardinalia and long supporting plates,  $\times 1$ , hypotype USNM 151040a; 4-6, side, anterior, and posterior views of a fragmentary pedicle valve, showing the tubular spondylium,  $\times 1$ , hypotype USNM 151223d; 7, 8, posterior and interior views of a small brachial valve,  $\times 1$ , hypotype USNM 151040b; 9, 10, same views of same specimen,  $\times 2$ ; 11-13, posterior, interior, and exterior views of a pedicle valve, showing the spondylium,  $\times 1$ , hypotype USNM 151223n [Bone Spring Formation (lower), locality USNM 728f].

14, 15, Posterior and interior of another brachial valve fragment, showing cardinalia,  $\times 1$ , hypotype USNM 153479; 16-18, partial side, posterior, and interior views of the preceding specimen, showing the short, stout cardinal process and long supporting plates,  $\times 2$  [Bone Spring Formation (lower), locality AMNH 628].

*Goniarina* species 5: 19, Interior of a fragmentary brachial valve, showing sockets and cardinal process,  $\times 4$ , figured specimen USNM 153549 [Cathedral Mountain Formation (lower), locality USNM 721u].



PLATE 94.—*Orthotetella* and *Goniarrina*.



## PLATE 95

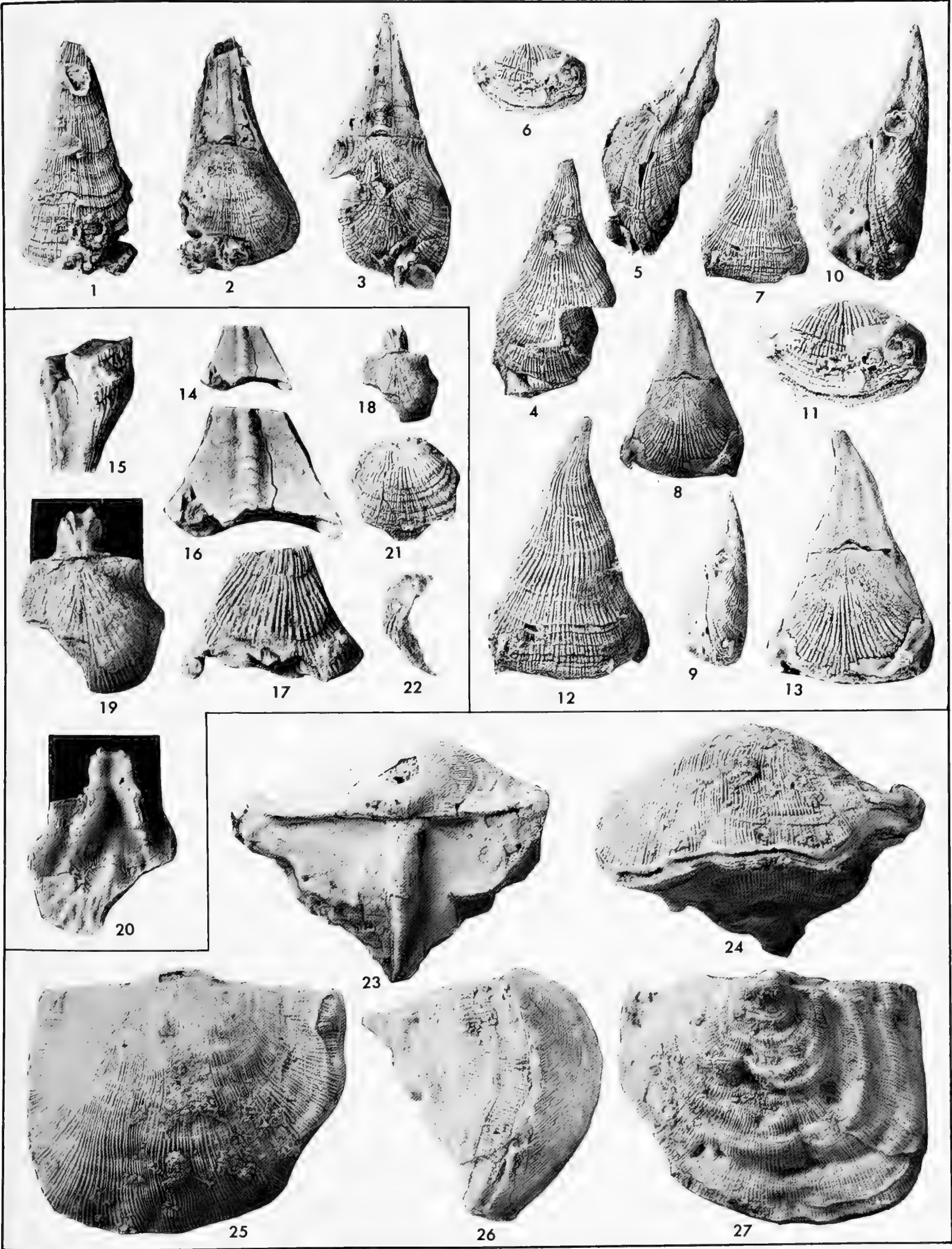
*Chelononia* and *Orthotetella*

*Chelononia straminea*, new species: 1, 2, Ventral and dorsal views of a large specimen,  $\times 1$ , hypotype USNM 147883c; 3-5, dorsal, ventral, and side views of another large specimen,  $\times 1$ , hypotype USNM 147883b; 6-9, anterior, ventral, dorsal, and side views of a nearly perfect specimen,  $\times 1$ , hypotype USNM 147884; 10-13, side, anterior, ventral, and dorsal views of the same specimen,  $\times 1.5$  [Neal Ranch Formation, locality USNM 701d].

*Streptorhynchus pyramidale* R. E. King [= *Chelononia straminea*, new species]: 14, Posterior of a fragmentary pedicle valve,  $\times 1$ , holotype YPM 11392a; 15-17, side, posterior, and exterior views of the same specimen,  $\times 2$ ; 18, exterior of a brachial valve,  $\times 1$ , paratype YPM 11392b; 19, 20, exterior and interior of the preceding specimen,  $\times 2$ ; 21, 22, exterior and side views of another brachial valve,  $\times 1$ , paratype YPM 11392c [Neal Ranch Formation, R. E. King locality 93]

*Orthotetella wolfcampensis* R. E. King: 23-27, Posterior, anterior, dorsal, side, and ventral views of a large, complete specimen,  $\times 1$ , hypotype USNM 151217 [Neal Ranch Formation (bed 12 of P. B. King), locality USNM 701h].

PLATE 95.—*Chelononia* and *Orthotetella*.

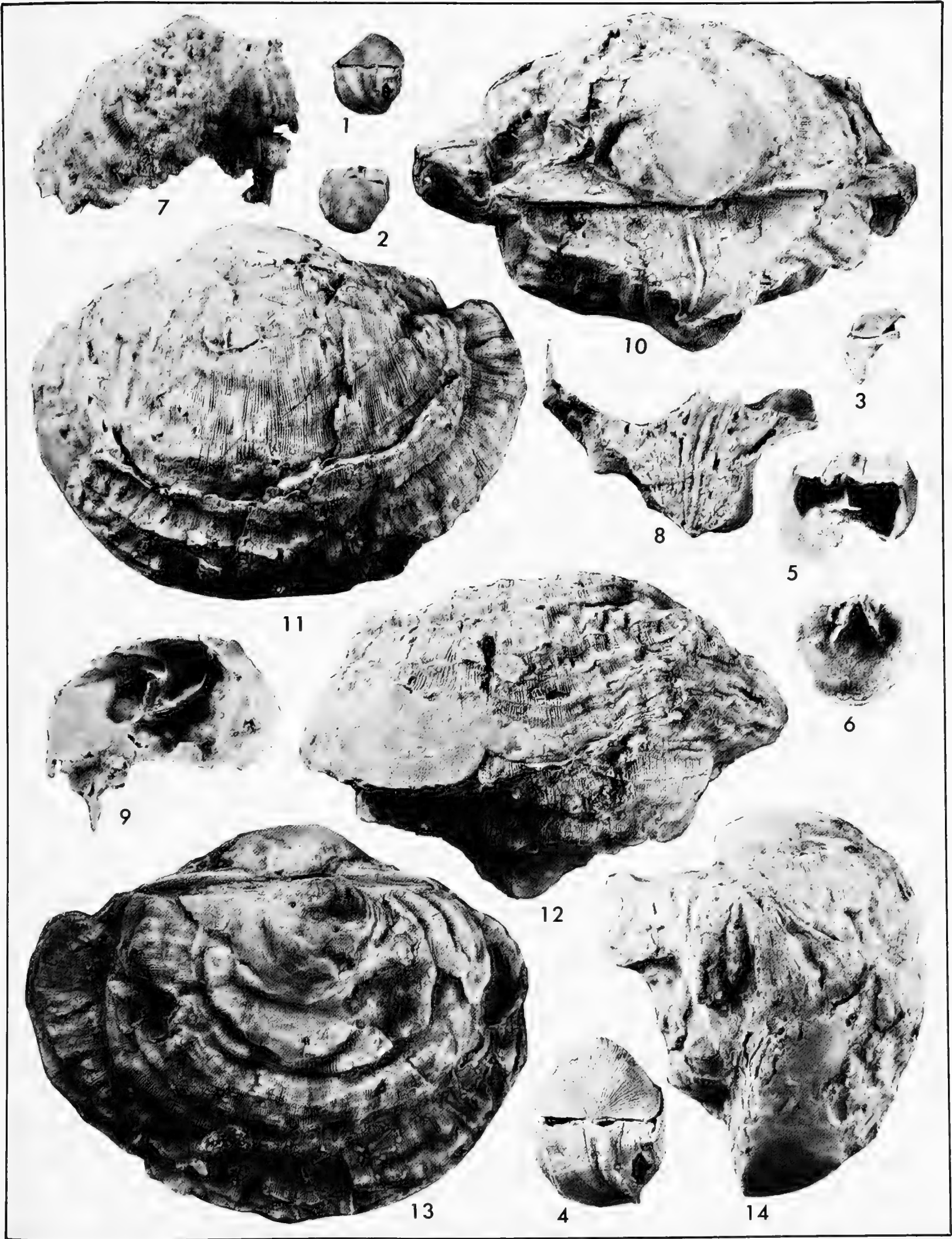


**PLATE 96***Nothopindax*

*Nothopindax egregius*, new species: 1-3, Posterior, dorsal, and side views of an immature paratype,  $\times 1$ , USNM 151225a; 4, posterior of preceding specimen showing pseudodeltidium,  $\times 2$ ; 5, 6, interior of the pedicle and brachial valves of the same paratype, showing septum with bare and long supporting plates to the cardinal process,  $\times 2$ ; 7-9, exterior, posterior, and laterally tilted views of an imperfect pedicle valve, showing chamber in posterior part of septum and supporting plate under bar of septum,  $\times 1$ , paratype USNM 151226e; 10-14, posterior, dorsal, anterior, ventral, and side views of a medium-sized specimen,  $\times 1$ , paratype USNM 151226a [Neal Ranch Formation (beds 12-14 of P. B. King), USNM 701h].



PLATE 96.—*Nothopindax*.

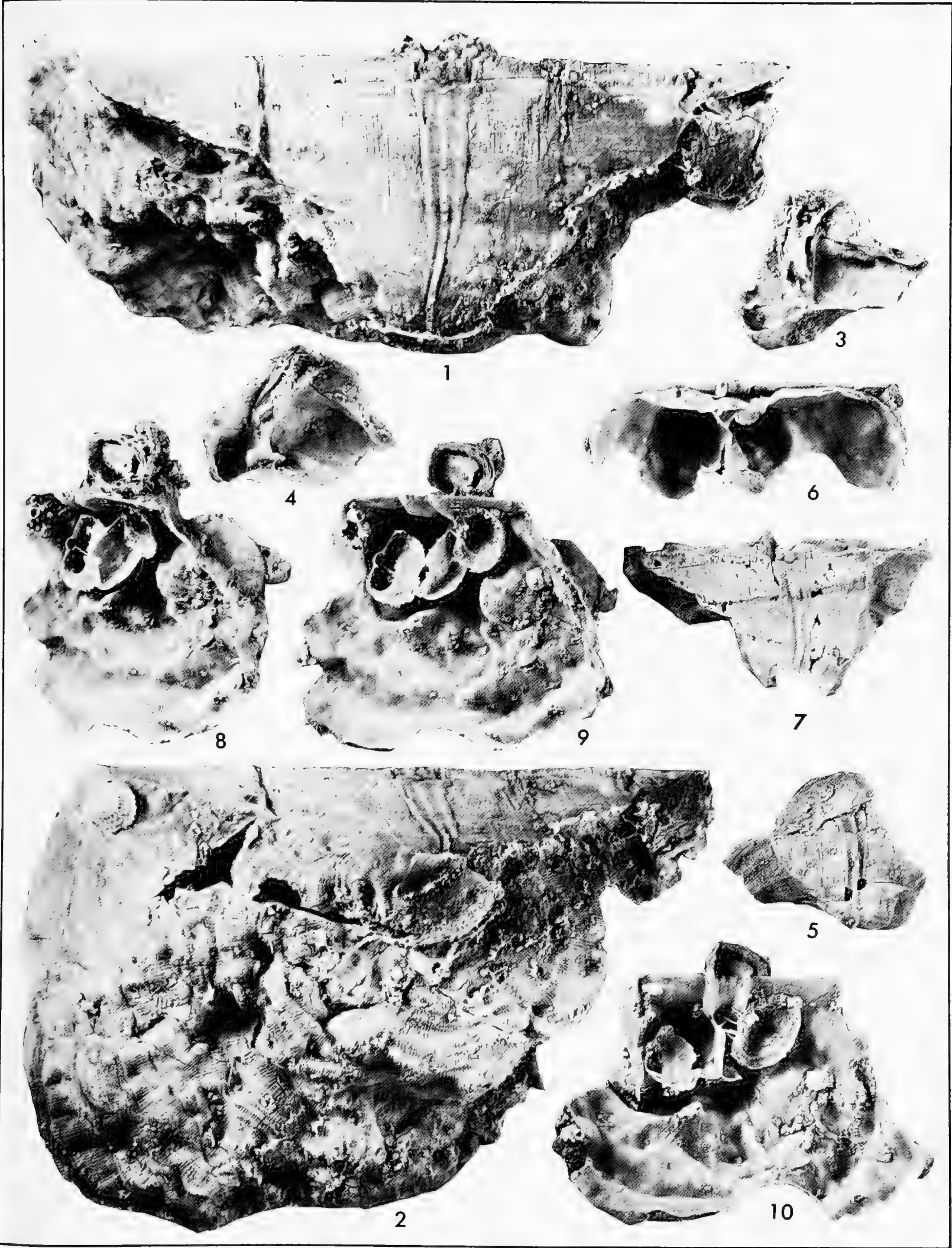




**PLATE 97***Nothopindax*

*Nothopindax egregius*, new species: 1, 2, Posterior and ventral views of a large pedicle valve,  $\times 1$ , paratype USNM 151225e (see Plate 96 for additional views); 3–5, postero-interior, dorsal, and posterior views of a small specimen, showing cardinal process and septum with cross-bar and supporting plate,  $\times 1$ , paratype USNM 151226c; 6, 7, interior and posterior views of another pedicle valve, showing small chamber between pseudodeltidium and septum,  $\times 1$ , paratype USNM 151225b; 8–10, posterolaterally tilted, laterally tilted, and full views of a much encrusted pedicle valve, showing chamber, septum, cross-bar, and its supporting plate,  $\times 1$ , paratype USNM 151225d [Neal Ranch Formation (beds 12–14 of P. B. King), USNM 701h].

PLATE 97.—*Nothopindax*.



## PLATE 98

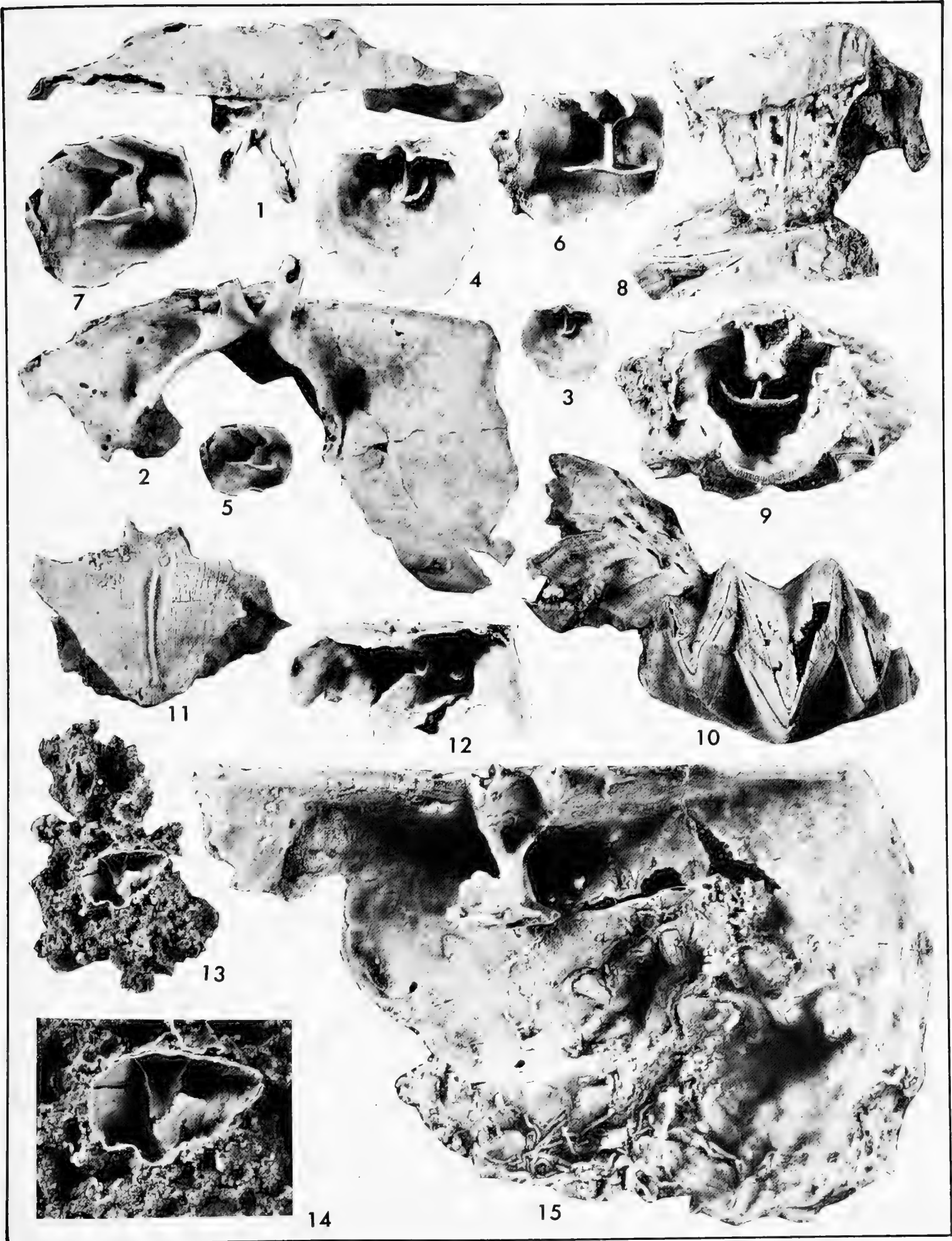
*Nothopindax*

*Nothopindax egregius*, new species: 1, 2, Posterior and interior views of a large brachial valve, showing the cardinal process,  $\times 1$ , paratype USNM 153468 [Neal Ranch Formation (bed 9 of Cooper), USNM 701a].

3, Interior of an immature pedicle valve, showing early stage of development of septum and cross-bar,  $\times 1$ , paratype USNM 151227a; 4, same tilted laterally,  $\times 2$ ; 5, another immature pedicle valve, showing septum and cross-bar free of valve floor,  $\times 1$ , paratype USNM 151227b; 6, 7, full and laterally tilted views of the same specimen, showing apical chamber, septum, and cross-bar free of the valve floor and without a supporting plate,  $\times 2$  [Neal Ranch Formation (bed 12 of P. B. King), USNM 701k].

8-10, posterior, dorsal, and side views of a small individual attached to *Parenteleles*, showing cardinal process and septum with cross-bar,  $\times 1$ , holotype USNM 151225c; 11, posterior of a pedicle valve, showing pseudodeltidium and narrow, longitudinal fold down its middle,  $\times 1$ , paratype USNM 151226d; 12, interior of a pedicle valve, showing septum and apical chamber,  $\times 1$ , paratype USNM 151225b; 13, 14, immature specimen cemented in algal (?) debris,  $\times 1$ ,  $\times 2$ , paratype USNM 151225f; 15, interior of a large paratype, showing apical chamber, septum, and cross-bar,  $\times 1$ , USNM 151225e (for additional views of the exterior of this specimen, see Plate 97) [Neal Ranch Formation (beds 12-14 of P. B. King), USNM 701h].

PLATE 98.—*Nothopindax*.



## PLATE 99

*Meekella*

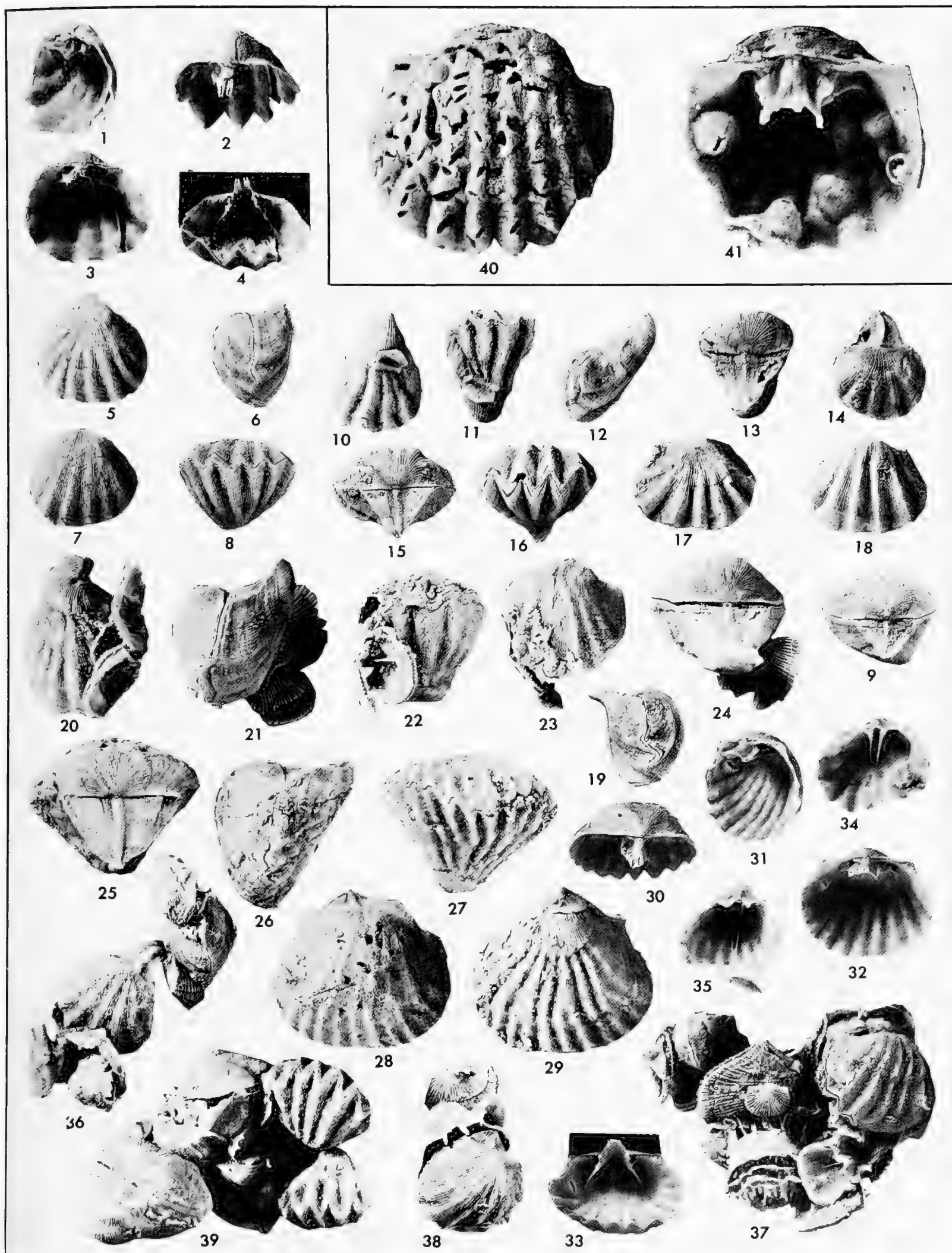
*Meekella prionota*, new species: 1-4, Laterally tilted, posterior, interior, and anterior views of a small adult,  $\times 1$ , paratype USNM 153539a; 5-9, ventral, side, dorsal, anterior, and posterior views of a complete small adult,  $\times 1$ , paratype USNM 153539c; 10-14, ventral, anterior, side, posterior, and dorsal views of a young specimen with elongated pedicle valve,  $\times 1$ , paratype USNM 153539d; 15-19, posterior, anterior, ventral, dorsal, and side views of a small coarsely costated adult,  $\times 1$ , paratype USNM 153539e; 20-24, ventral, side, anterior, dorsal, and posterior views of a large individual,  $\times 1$ , paratype USNM 153539g; 30-33, posterior, laterally tilted, interior, and anterior views of a brachial valve,  $\times 1$ , paratype USNM 153539b; 34, interior of a small pedicle valve,  $\times 1$ , paratype USNM 153539f; ~~35, interior of a small pedicle valve,  $\times 1$ , paratype USNM 150616b;~~ 36, specimen attached among *Derbyia bella*,  $\times 1$ , paratype USNM 153539h; 37-39, clusters of cemented individuals,  $\times 1$ , paratype USNM 150616a [Neal Ranch Formation (beds 12-14 of P. B. King), locality USNM 701k]. <sup>153539f</sup>

25-29, Posterior, side anterior, dorsal, and pedicle views of a large individual,  $\times 1$ , paratype USNM 150616a; 35, interior of a small pedicle valve,  $\times 1$ , paratype USNM 150616b [Neal Ranch Formation (beds 12-14 of P. B. King), locality USNM 701k].

*Meekella skenoides* Girty: 40, 41, Exterior and interior of a small brachial valve riddled by borings of a barnacle and the blisters or cysts on the interior resulting from the boring,  $\times 3$ , hypotype USNM 153538 [Word Formation (Willis Ranch Member), locality USNM 706e].



PLATE 99.—*Meekella*.

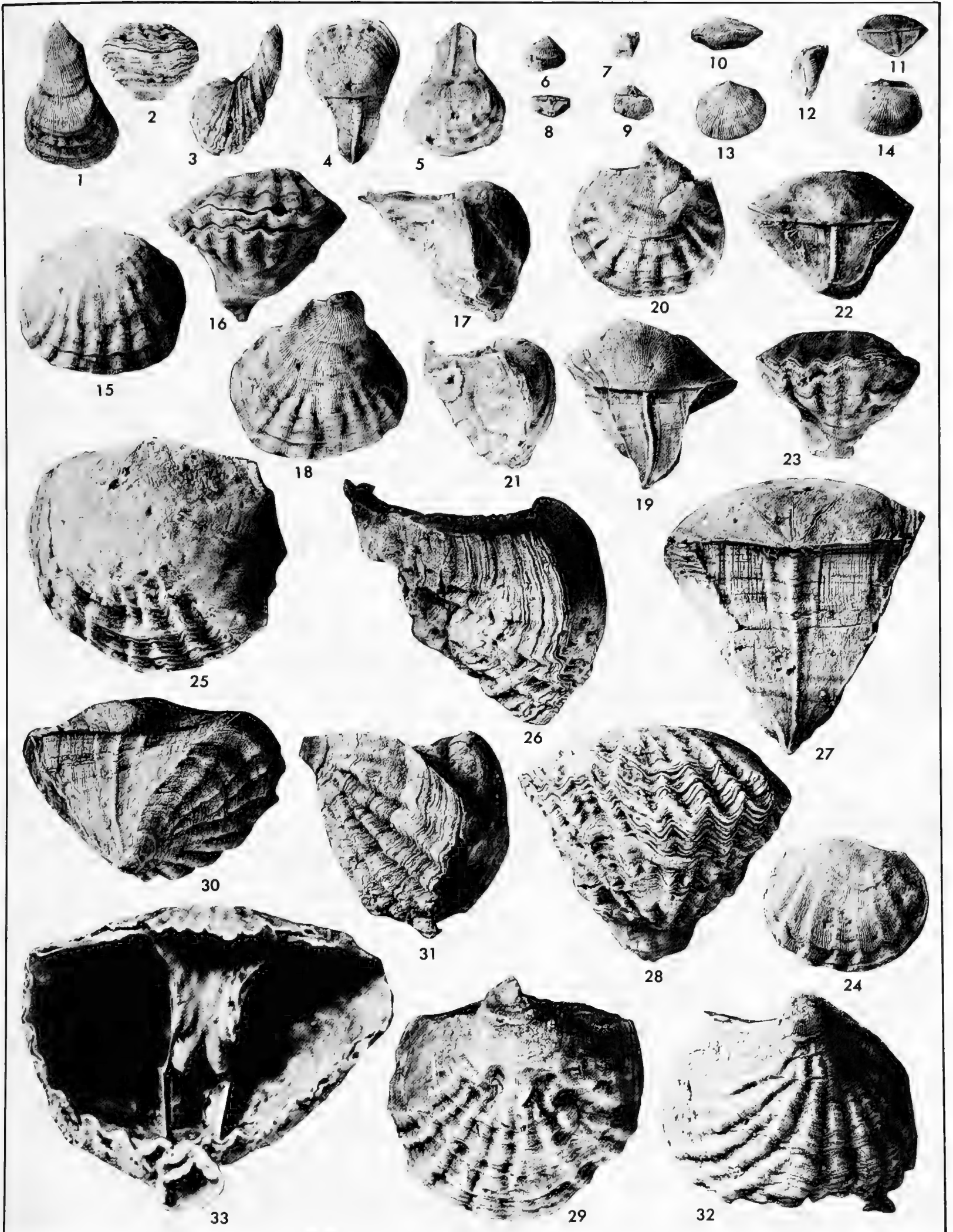


## PLATE 100

*Meekella*

*Meekella magnifica*, new species: 1-5, Ventral, anterior, side, posterior, and dorsal views of an immature individual with costellate apical region,  $\times 1$ , paratype USNM 150578j; 6-9, ventral, side, posterior, and dorsal views of an immature, wholly costellate specimen,  $\times 1$ , paratype USNM 150578a; 10-14, anterior, posterior, side, ventral, and dorsal views of a costellate young specimen,  $\times 1$ , paratype USNM 150578g; 15-19, dorsal, anterior, side, ventral, and posterior views of a young specimen,  $\times 1$ , paratype USNM 150578r; 20-24, ventral, side, posterior, anterior and dorsal views of a complete young adult,  $\times 1$ , paratype USNM 150578q; 25-29, dorsal, side, posterior, anterior, and ventral views of a large adult,  $\times 1$ , holotype USNM 150578x; 30-32, posterior, side, and ventral views of another large individual,  $\times 1$ , paratype USNM 153535e; 33, interior of a large adult, showing the cardinal process in anterior view,  $\times 1$ , paratype USNM 150570 [Neal Ranch Formation (bed 9 of Cooper) locality USNM 701g].

PLATE 100.—*Meekella*.



## PLATE 101

*Meekella*, *Echinosteges*, and *Tropidelasma*

*Meekella circularis*, new species: 1–5, Ventral, dorsal, posterior, side, and anterior views of a large individual,  $\times 1$ , holotype USNM 152613d; 6, 7, posterior and interior views of the brachial valve of the preceding specimen,  $\times 1$ ; 8, interior of the pedicle valve of the preceding specimen, showing convergent dental lamellae,  $\times 1$  [Hueco Formation, locality AMNH 700].

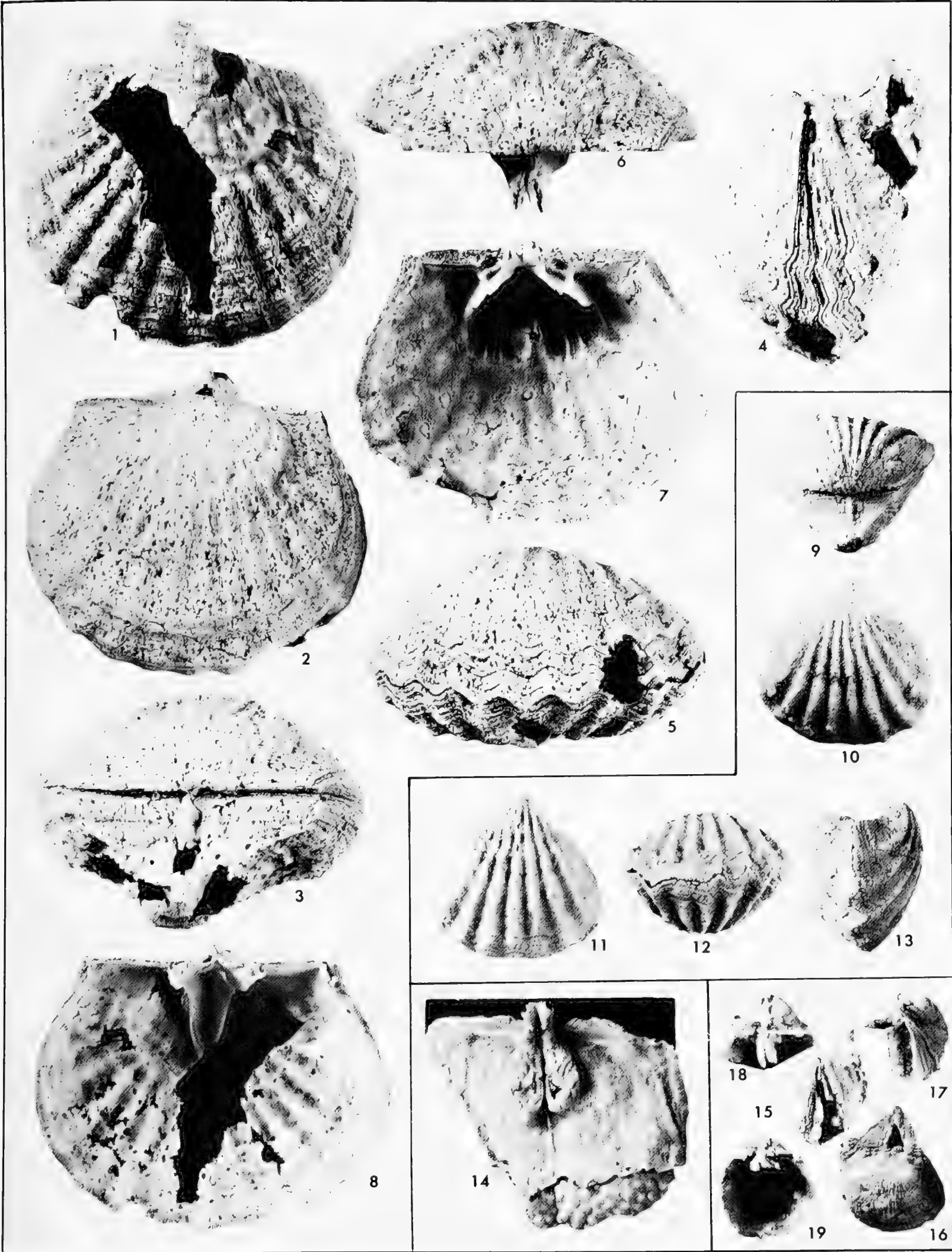
*Meekella skenoides* Girty: 9–13, Posterior, dorsal, ventral, anterior, and side views of a complete specimen,  $\times 1$ , hypotype USNM 155127 [Basal Cherry Canyon Formation, locality AMNH Boyd B188–8].

*Echinosteges tuberculatus* (R. E. King): 14, Interior of a brachial valve,  $\times 1$ , hypotype USNM 154529 [Road Canyon Formation, locality USNM 732j].

*Tropidelasma* species 3: 15, 16, Side and dorsal views of a complete specimen,  $\times 1$ , figured specimen USNM 152600a; 17–19, side, posterior, and ventral views of a brachial valve, showing the cardinal process,  $\times 1$ , figured specimen USNM 152600b [Skinner Ranch Formation, locality USNM 723–1].



PLATE 101.—*Meekella*, *Echinosteges*, and *Tropidelasma*.



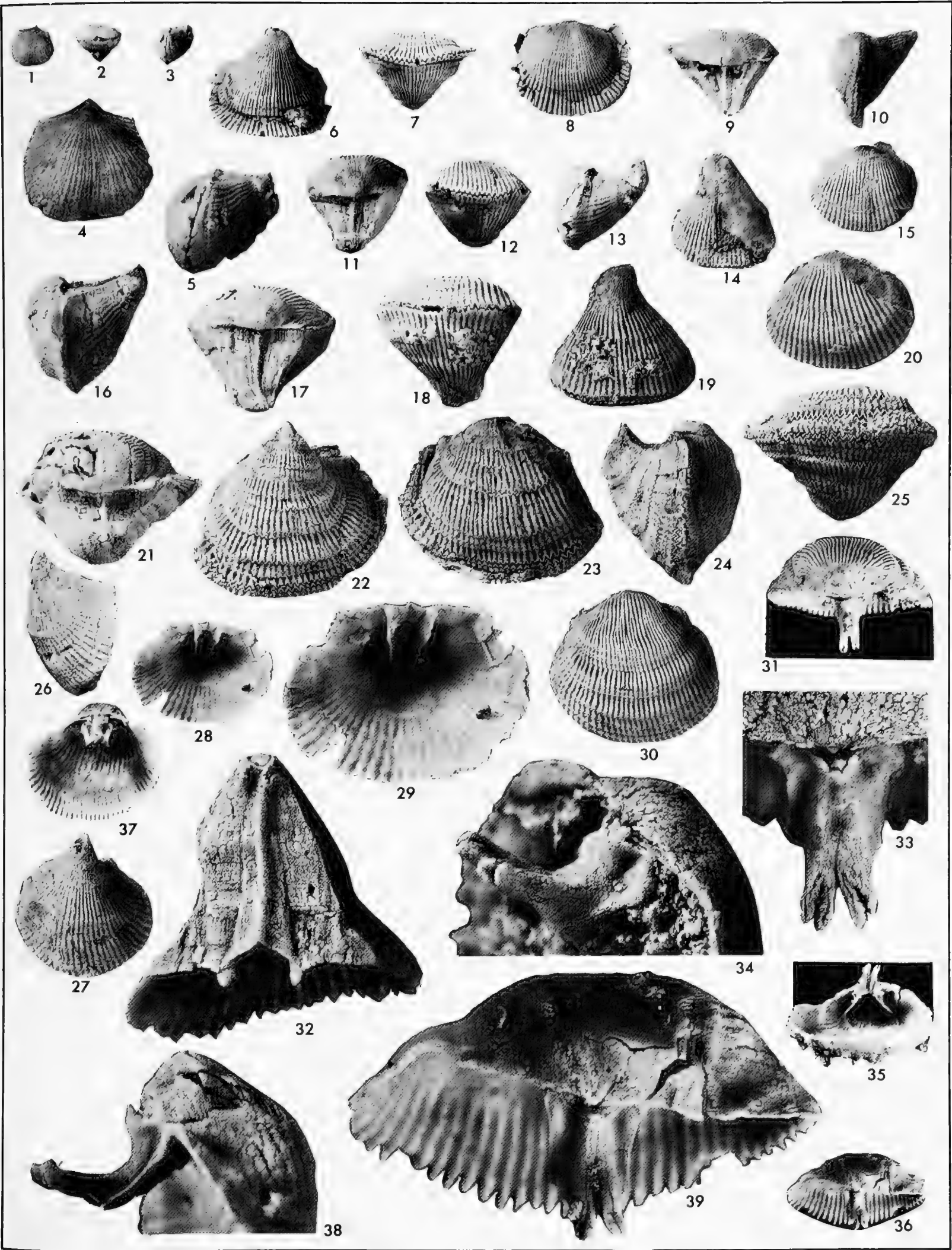


## PLATE 102

*Meekella*

*Meekella angustiplicata*, new species: 1-3, Dorsal, anterior, and side views of an immature specimen,  $\times 1$ , paratype USNM 150886b; 4, 5, dorsal and side views of the preceding specimen, showing fine costellate immature stage  $\times 3$ ; 6-10, ventral, anterior, dorsal, posterior, and side views of a small individual,  $\times 1$ , paratype USNM 150886k; 11-15, posterior, anterior, side, ventral, and dorsal views of another small specimen,  $\times 1$ , paratype USNM 150886e; 16-20, side, posterior, anterior, ventral, and dorsal views,  $\times 1$ , holotype USNM 150886g; 21-25, posterior, ventral, dorsal, side, and anterior views of a large adult,  $\times 1$ , paratype USNM 150886j; 26, 27, side and ventral views of a pedicle valve,  $\times 1$ , paratype USNM 150886-1; 28, 29, interior of the pedicle valve,  $\times 1$ ,  $\times 2$ , paratype USNM 150886m; 30, 31, exterior and interior of a brachial valve, showing long cardinal process,  $\times 1$ , paratype USNM 150886n; 32, interarea of the pedicle valve, showing pseudodeltidium with its prominent monticulus,  $\times 3$ , paratype USNM 150886o; 33, 34, posterior and lateral views, showing cardinal process with remnantal chilidium,  $\times 4$ , paratype USNM 150886p; 35-37, anterior, posterior, and interior views of a brachial valve, showing the cardinalia,  $\times 1$ , paratype USNM 150886q; 38, 39, side and posterior views of the cardinal process of the preceding specimen, showing chilidium, promontorium, and myophore,  $\times 4$  [Bone Spring Formation, locality USNM 725c].

PLATE 102.—*Meekella*.

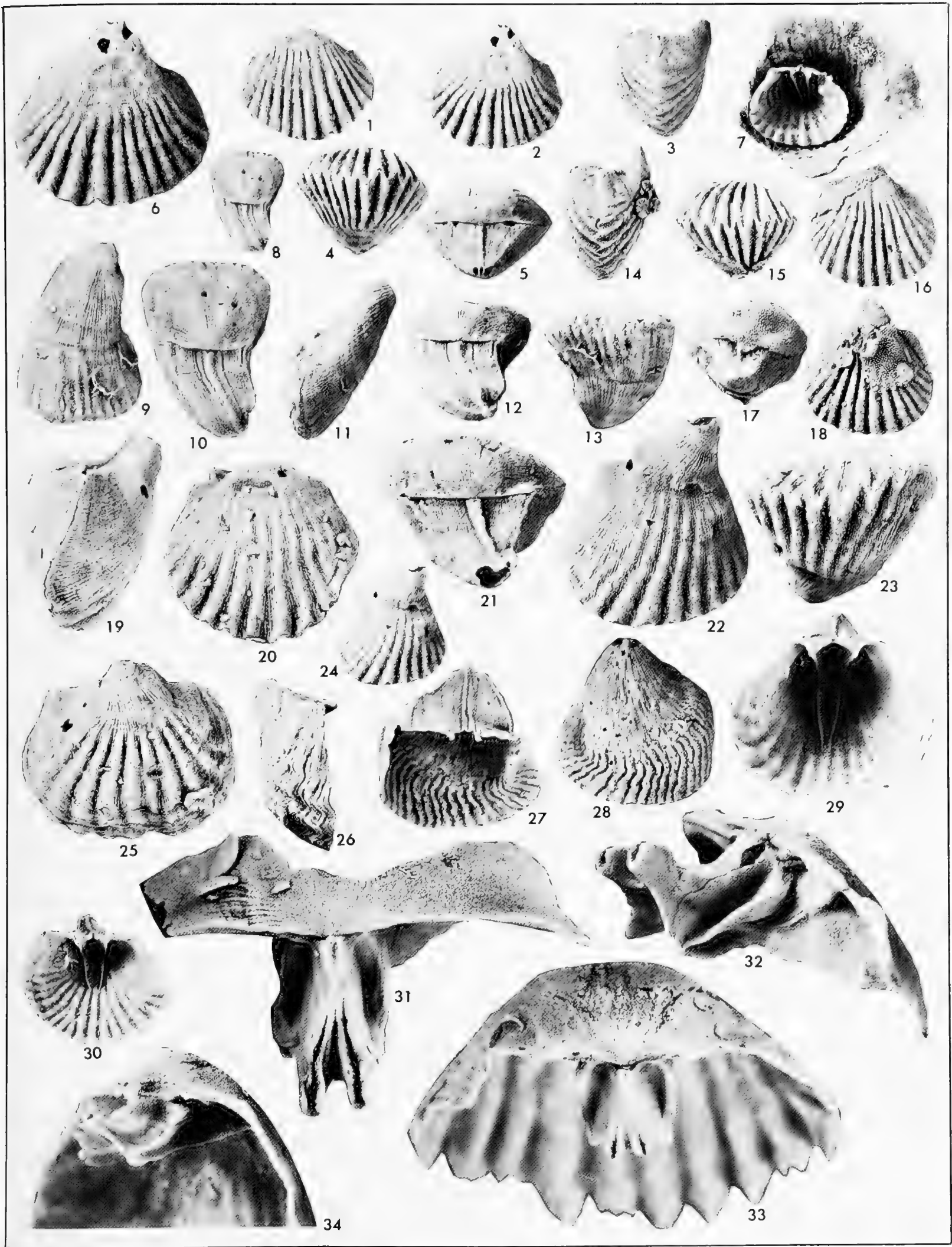


## PLATE 103

*Meekella*

*Meekella attenuata* Girty: 1-5, Dorsal, ventral, side, anterior, and posterior views of a complete specimen,  $\times 1$ , hypotype USNM 153517a; 6, ventral view of the same specimen showing costellate immature ornament at apical region,  $\times 2$ ; 7, small pedicle valve attached to a productacean brachial valve,  $\times 1$ , hypotype USNM 153517n; 8 posterior of an elongated, immature specimen,  $\times 1$ , hypotype USNM 150894n; 9-13, ventral, dorsal, side, posterior, and anterior views of the preceding,  $\times 2$ ; 14-18, side, anterior, dorsal, posterior, and ventral views of a larger specimen,  $\times 1$ , hypotype USNM 153517b; 19-23, side, dorsal, posterior, ventral and anterior views of a small adult,  $\times 2$ , hypotype USNM 150894k; 24, the same in ventral view,  $\times 1$ ; 25, 26, ventral and side views of a large pedicle valve with strong costae and costellate apex,  $\times 1$ , hypotype USNM 151043a; 27, 28, interior and exterior of a pedicle valve having aberrant ornament,  $\times 1$ , hypotype USNM 153517c; 29, interior of the pedicle valve, showing convergent dental plates,  $\times 1.5$ , hypotype USNM 153517d; 30, interior of another pedicle valve, showing convergent dental plates but more distant than the preceding,  $\times 1$ , hypotype USNM 153517e; 31, 32, posterior and side views of a well-formed cardinal process, showing promontorium and myophore,  $\times 4$ , hypotype USNM 153517f; 33, 34, posterior and side views of the cardinal process of another brachial valve,  $\times 4$ , hypotype USNM 153517g [Bone Spring Formation (lower), locality USNM 728e].

PLATE 103.—*Meekella*.



## PLATE 104

*Meekella*

*Meekella skenoides* Girty: 1, 2, Side view of a complete specimen, showing the long cardinal process and its relationship to the teeth,  $\times 2$ ,  $\times 1.5$ , hypotype USNM 153518 [Word Formation (China Tank Member), locality USNM 706c].

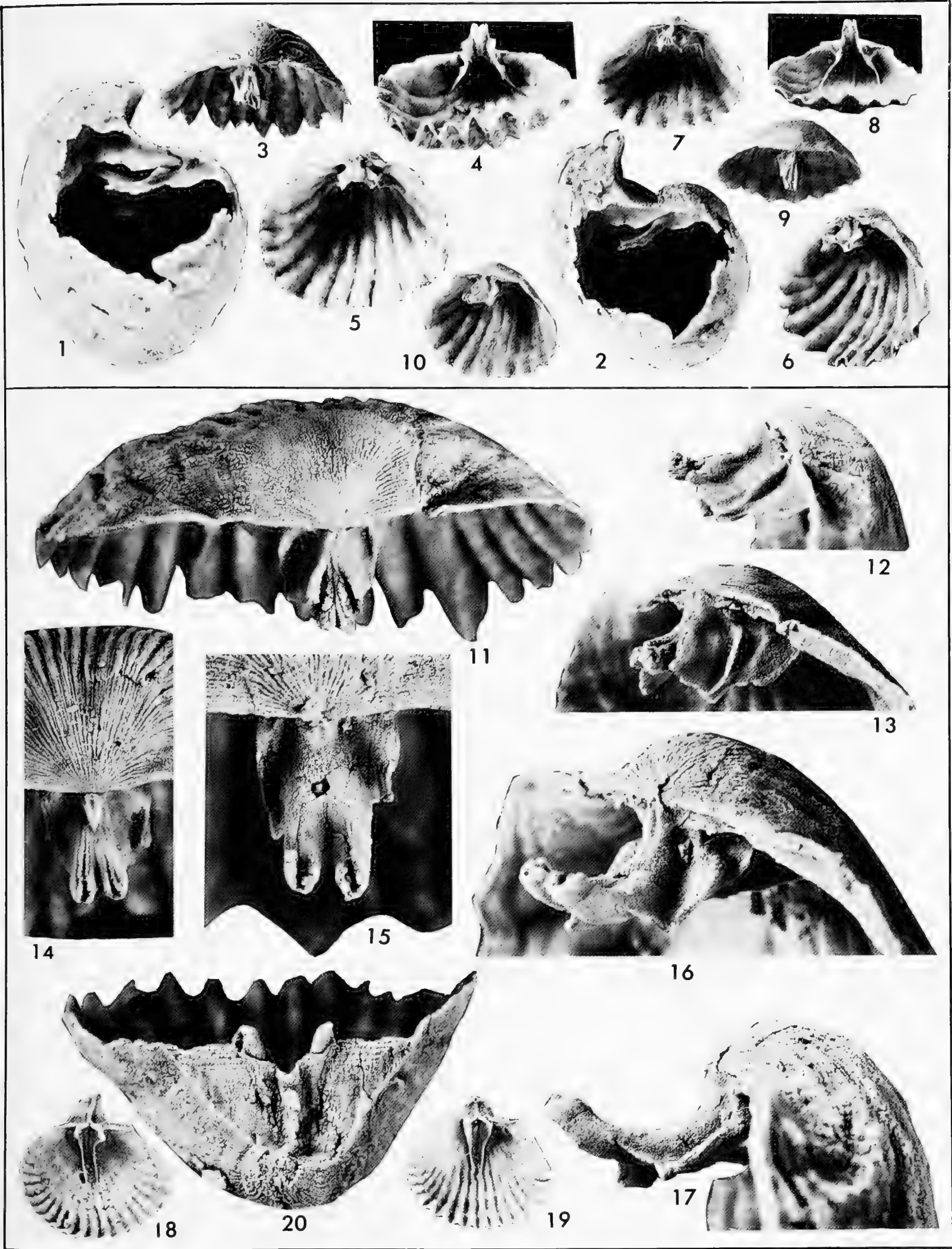
3-6, Posterior, anterior, interior, and laterally tilted views of a large brachial valve,  $\times 1$ , hypotype USNM 150554b [Cherry Canyon Formation (Getaway Member), locality USNM 728].

7-10, Interior, anterior, posterior, and tilted views of a smaller brachial valve,  $\times 1$ , hypotype USNM 153519 [Word Formation (Willis Ranch Member), locality USNM 706].

*Meekella attenuata* Girty: 11-13, Posterior, side, and laterally tilted views of the cardinal process, showing a narrowly restricted myophore,  $\times 4$ , hypotype USNM 153517h; 14, cardinal process of another brachial valve, showing an elongated chilidium,  $\times 4$ , paratype USNM 153517i; 15-17, posterior, laterally tilted, and side views of a large cardinal process, showing myophore and promontorium,  $\times 4$ , hypotype USNM 153517j; 18, interior of a pedicle valve, showing monticulus on interarea,  $\times 1$ , hypotype USNM 153517k; 19, another pedicle valve interior, showing narrow delthyrial cavity,  $\times 1$ , hypotype USNM 153517-1; 20, posterior of pedicle valve, showing monticulus on pseudodeltidium,  $\times 3$ , hypotype USNM 153517m [Bone Spring Formation (lower), locality USNM 728e].



PLATE 104.—*Meekella*.



## PLATE 105

*Meekella*

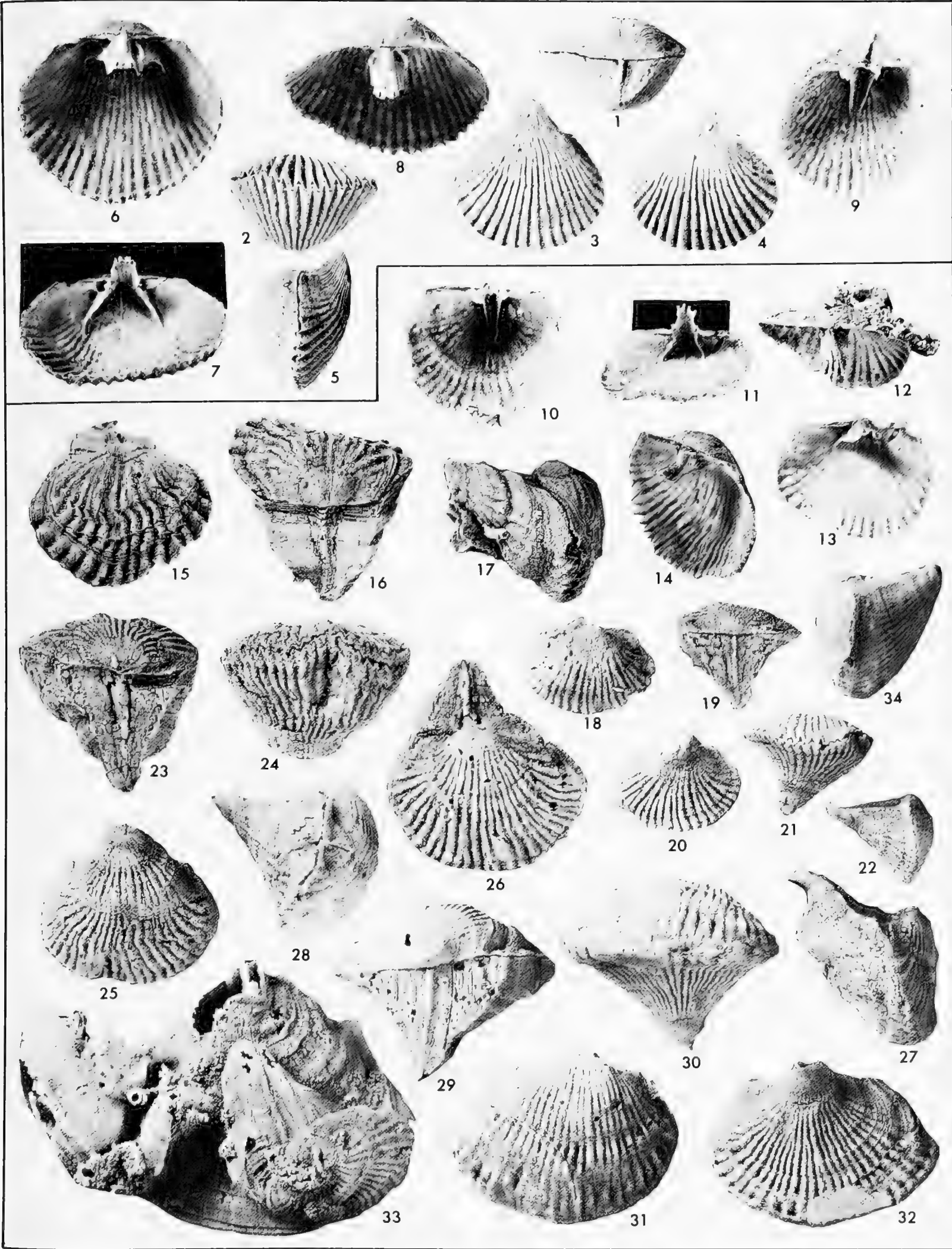
*Meekella intermedia*, new species: 1–5, Posterior, anterior, ventral, dorsal, and side views,  $\times$  1, holotype USNM 150902a; 6–8, interior, anterior, and posterior views of the brachial valve, showing the cardinalia,  $\times$  1, paratype USNM 150902c; 9, interior of the pedicle valve,  $\times$  1, paratype USNM 150902b [Bone Spring Formation (lower), locality USNM 728f].

*Meekella caperata*, new species: 10, Interior of the pedicle valve,  $\times$  1, paratype USNM 15351a; 11–13, anterior, posterior, and interior views of the brachial valve,  $\times$  1, paratype USNM 15351b; 14, laterally tilted view of another brachial valve,  $\times$  1, paratype USNM 15351c; 15–17, dorsal, posterior, and side views of a complete specimen,  $\times$  1, paratype USNM 15351d [Skinner Ranch Formation (Decie Member), locality USNM 701w].

18–22, Dorsal, posterior, ventral, anterior, and side views of a young individual,  $\times$  1, paratype USNM 150499c; 23–27, posterior, anterior, ventral, dorsal, and side views of an adult,  $\times$  1, paratype USNM 150499a; 28–32, side, posterior, anterior, dorsal, and ventral views of a large adult,  $\times$  1, holotype USNM 150499f; 33, adult attached to a large *Derbyia*,  $\times$  1, paratype USNM 151026 [Skinner Ranch Formation (lower), locality USNM 705a].

34, Side view of an unsilicified specimen,  $\times$  1, figured specimen USNM 150500 [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 707].

PLATE 105.—*Meekella*.



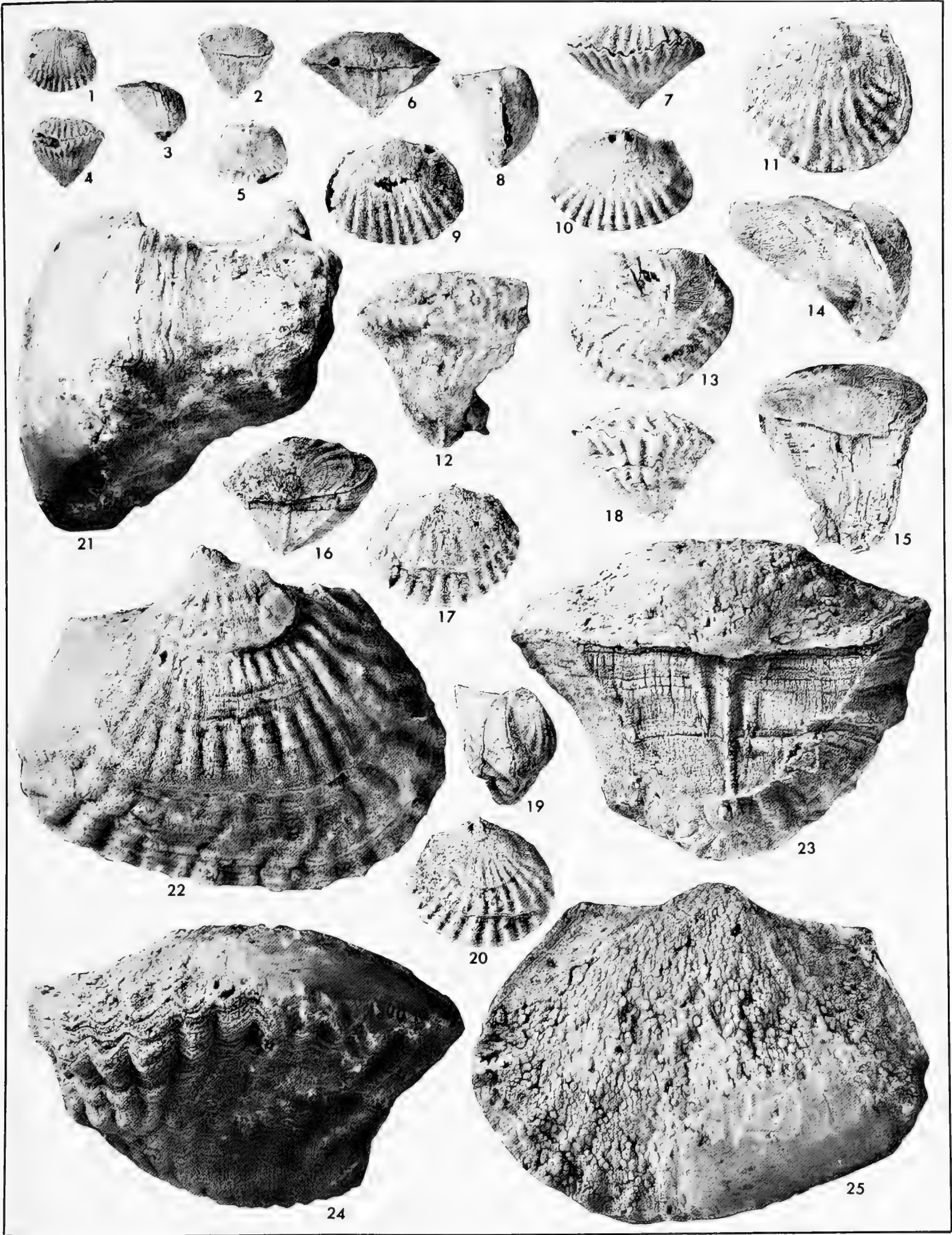
## PLATE 106

*Meekella*

*Meekella enormis*, new species: 1-5, Dorsal, posterior, side, anterior, and ventral views of an immature specimen, showing the predominantly costellate ornament of the young,  $\times 1$ , paratype USNM 150890c; 6-10, posterior, anterior, side, dorsal, and ventral views of a larger individual with well-developed costae,  $\times 1$ , paratype USNM 150890e; 11-15, dorsal, anterior, ventral, side, and posterior views of a larger specimen,  $\times 1$ , paratype USNM 150890i; 16-20, posterior, dorsal, anterior, side, and ventral views of a small adult,  $\times 1$ , paratype USNM 150890g; 21-25, side, ventral, posterior, anterior, and dorsal views of a fully grown adult,  $\times 1$ , holotype USNM 150890n [Skinner Ranch Formation (lower), locality USNM 720e].



PLATE 106.—*Meekella*.





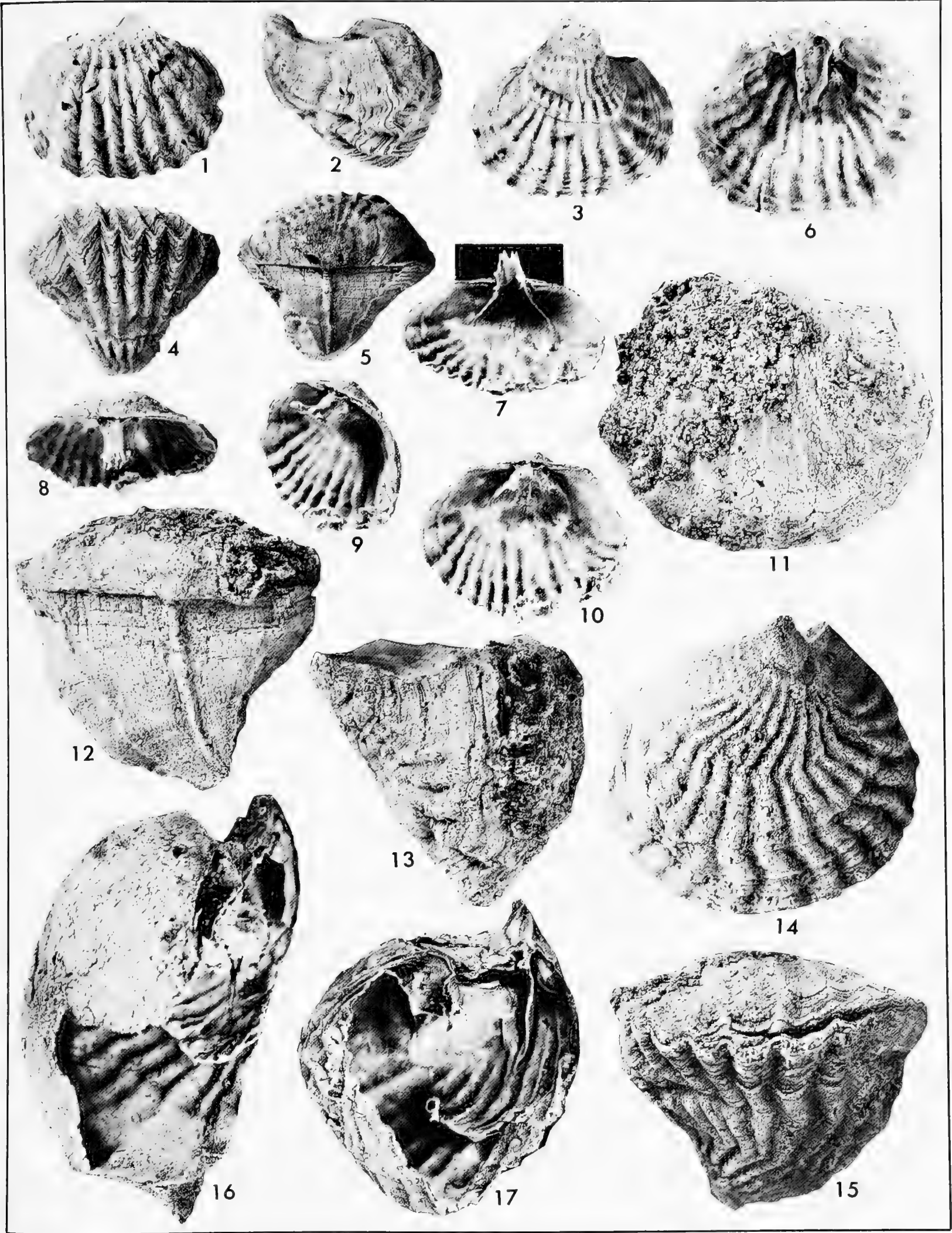
## PLATE 107

*Meekella*

*Meekella enormis*, new species: 1–5, Dorsal, side, ventral, anterior, and posterior views of a strongly costated specimen,  $\times 1$ , paratype USNM 150890j; 6, interior of a pedicle valve,  $\times 1$ , paratype USNM 153448a; 7–10, anterior, posterior, laterally tilted, and interior views of the brachial valve,  $\times 1$ , paratype USNM 153448c; 11–15, dorsal, posterior, side, ventral and anterior views of a large individual,  $\times 1$ , paratype USNM 150890m; 16, side view of a large specimen, showing elevated rim around muscle scars that surround the dental plates,  $\times 1$ , paratype USNM 150889 [Skinner Ranch Formation (lower), locality USNM 720e].

17, Another specimen, showing the thickened marginal rims to the muscle scars surrounding the dental plates,  $\times 1$ , paratype USNM 150596 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707w].

PLATE 107.—*Meekella*.



## PLATE 108

*Tropidelasma* and *Meekella*

*Tropidelasma undulatum* (R. E. King): 1-5, Anterior, posterior, side, ventral, and dorsal views, with outlines restored, of the lectotype, YPM 11406 [Skinner Ranch Formation (lower), R. E. King locality 211].

*Meekella skenoides* Girty: 6-9, Anterior, laterally tilted, posterior, and interior views of a brachial valve,  $\times 1$ , hypotype USNM 153534b [Word Formation (lens between Willis Ranch and Appel Ranch Members), locality USNM 706b].

10, Interior of a brachial valve,  $\times 1$ , hypotype USNM 150554c [Cherry Canyon Formation (Getaway Member), locality USNM 728].

*Meekella hessensis* R. E. King: 11-15, Posterior, dorsal, ventral, anterior, and side views of the holotype YPM 10950 [Skinner Ranch (upper), R. E. King locality 122].

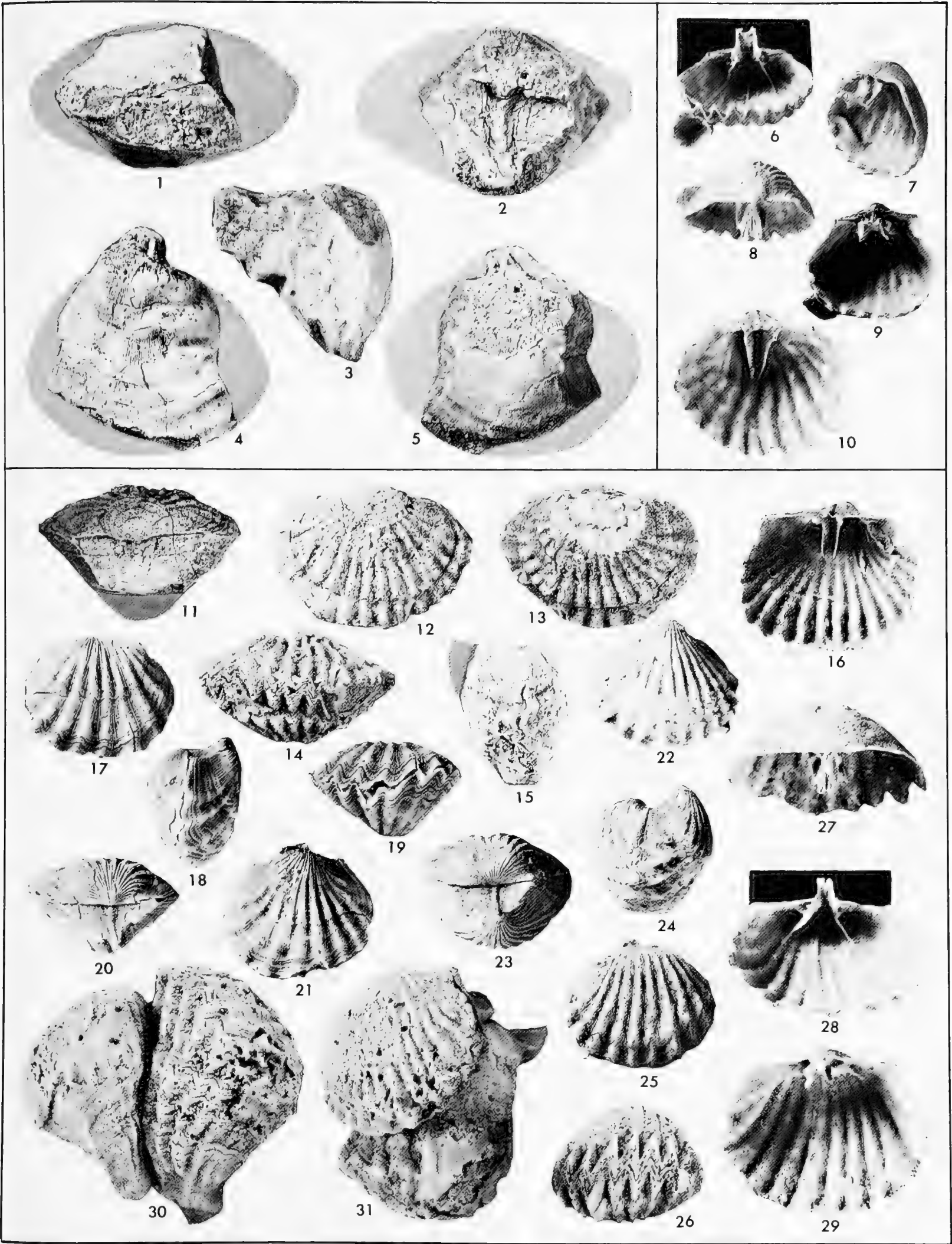
16, Interior of the pedicle valve,  $\times 1$ , hypotype USNM 152611a; 27-29, posterior, anterior, and interior views of the brachial valve,  $\times 1$ , hypotype USNM 152611b [Hess Formation (top), locality USNM 726n].

17-21, Dorsal, side, anterior, posterior, and ventral views of a strongly costated specimen,  $\times 1$ , hypotype USNM 152608a [Hess Formation (Taylor Ranch Member), locality USNM 702e].

22-26, Ventral, posterior, side, dorsal, and anterior views of another complete specimen,  $\times 1$ , hypotype USNM 152610 [Bone Spring Formation, locality AMNH 369].

30, 31, Two attached specimens,  $\times 1$ , hypotype USNM 153536 [Skinner Ranch Formation (lower), locality USNM 716t].

PLATE 108.—*Tropidelasma* and *Meekella*.



## PLATE 109

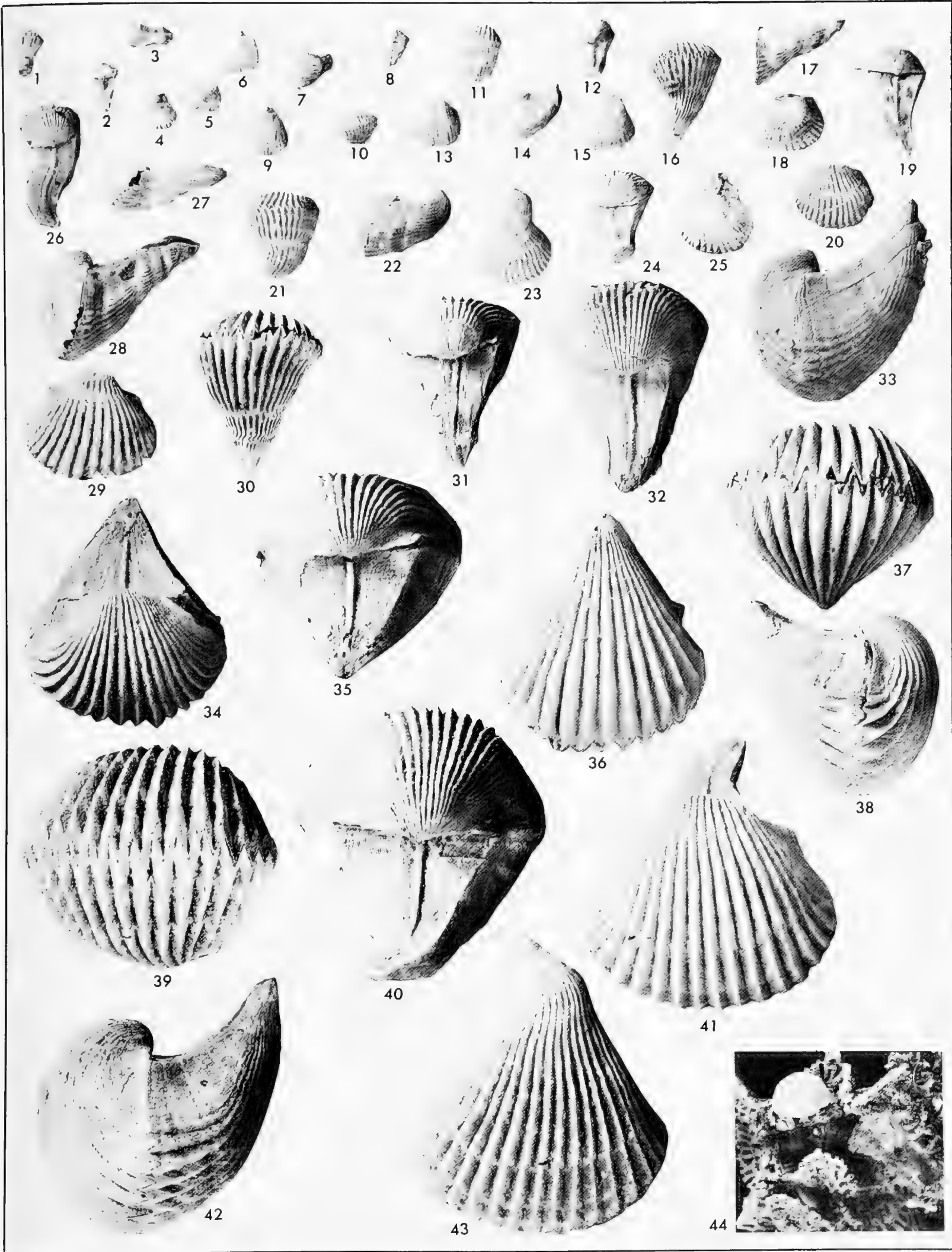
*Niviconia*

*Niviconia globosa* (R. E. King): 1-5, Anterior, posterior, side, dorsal, and ventral views of an immature but elongate specimen,  $\times 1$ , hypotype USNM 150516i; 6-10, dorsal, side, posterior, ventral, and anterior views of a stout but immature specimen,  $\times 1$ , hypotype USNM 150516h; 11-15, anterior, posterior, dorsal, side, and ventral views of an immature specimen larger than the preceding,  $\times 1$ , hypotype USNM 150516g; 16-20, anterior, side, ventral, posterior, and dorsal views of an elongate, young adult,  $\times 1$ , hypotype USNM 150516d; 21-25, anterior, side, ventral, posterior, and dorsal views of a small adult,  $\times 1$ , hypotype USNM 150516f; 26, 27, posterior and side views of an unusually elongated youthful specimen,  $\times 1$ , hypotype USNM 150516e; 28-31, side, dorsal, anterior, and posterior views of another elongated, young adult,  $\times 1$ , hypotype USNM 150516b; 34-38, dorsal, posterior, ventral, anterior, and side views of an adult,  $\times 1$ , hypotype USNM 150516j; 39-43, anterior, posterior, dorsal, side, and ventral views of a nearly perfect adult,  $\times 1$ , hypotype USNM 150517c; 44, a young specimen attached on a fenestellid colony,  $\times 1$ , hypotype USNM 150516k [Cathedral Mountain Formation (lower), locality USNM 702un].

32, 33, Posterior and side views of an elongated adult,  $\times 1$ , hypotype USNM 153532 [Cathedral Mountain Formation (lower), locality USNM 702 inst].



PLATE 109.—*Niviconia*.

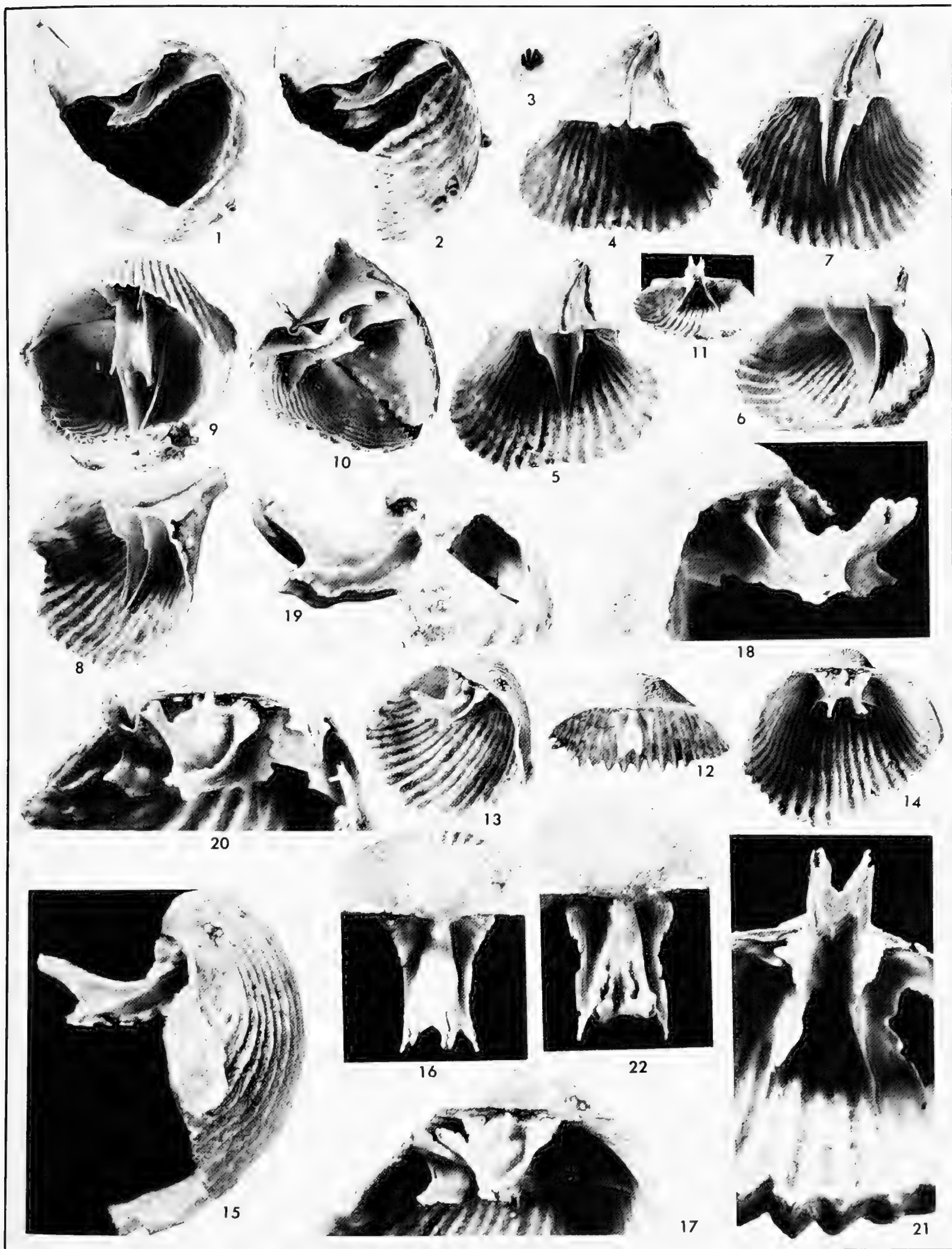


## PLATE 110

*Niviconia*

*Niviconia globosa* (R. E. King): 1, 2, Two side views of a broken specimen, showing cardinalia and dental plates,  $\times 1$ , hypotype USNM 153533a; 3, interior of an immature pedicle valve,  $\times 1$ , hypotype USNM 153533c; 4-6, posterior, interior, and laterally tilted views of a pedicle valve, showing convergent dental plates and monticulus on the pseudodeltidium,  $\times 1$ , hypotype USNM 153533b; 7, 8, interior and laterally tilted views of another pedicle valve, showing same features,  $\times 1$ , hypotype USNM 150516m; 9, interior of another specimen, showing cardinal process extending into delthyrial cavity,  $\times 1$ , hypotype USNM 153533c; 10, another interior tilted to show cardinal process and supporting plates,  $\times 1$ , hypotype USNM 150516n; 11, anterior view of the cardinal process of a small brachial valve  $\times 1$ , hypotype USNM 153533g; 12, posterior of another brachial valve, showing the cardinal process,  $\times 1$ , hypotype USNM 153533h; 13, 14, laterally tilted and interior views of the cardinal process of a mature adult,  $\times 1$ , hypotype USNM 153533i; 15-17, side, posterior, and laterally tilted views of the cardinal process of the preceding specimen, showing remnantal chilidium, promontorium, "brachio-phores", and promontorium, all  $\times 2$ ; 18-22, partial side, side, laterally tilted, anterior, and posterior views of the cardinal process of an old adult, showing socket plates, promontorium, and myophore, all  $\times 2$ , hypotype USNM 150516-1 [Cathedral Mountain Formation (lower), locality USNM 702un].

PLATE 110.—*Niviconia*.



## PLATE 111

*Meekella*

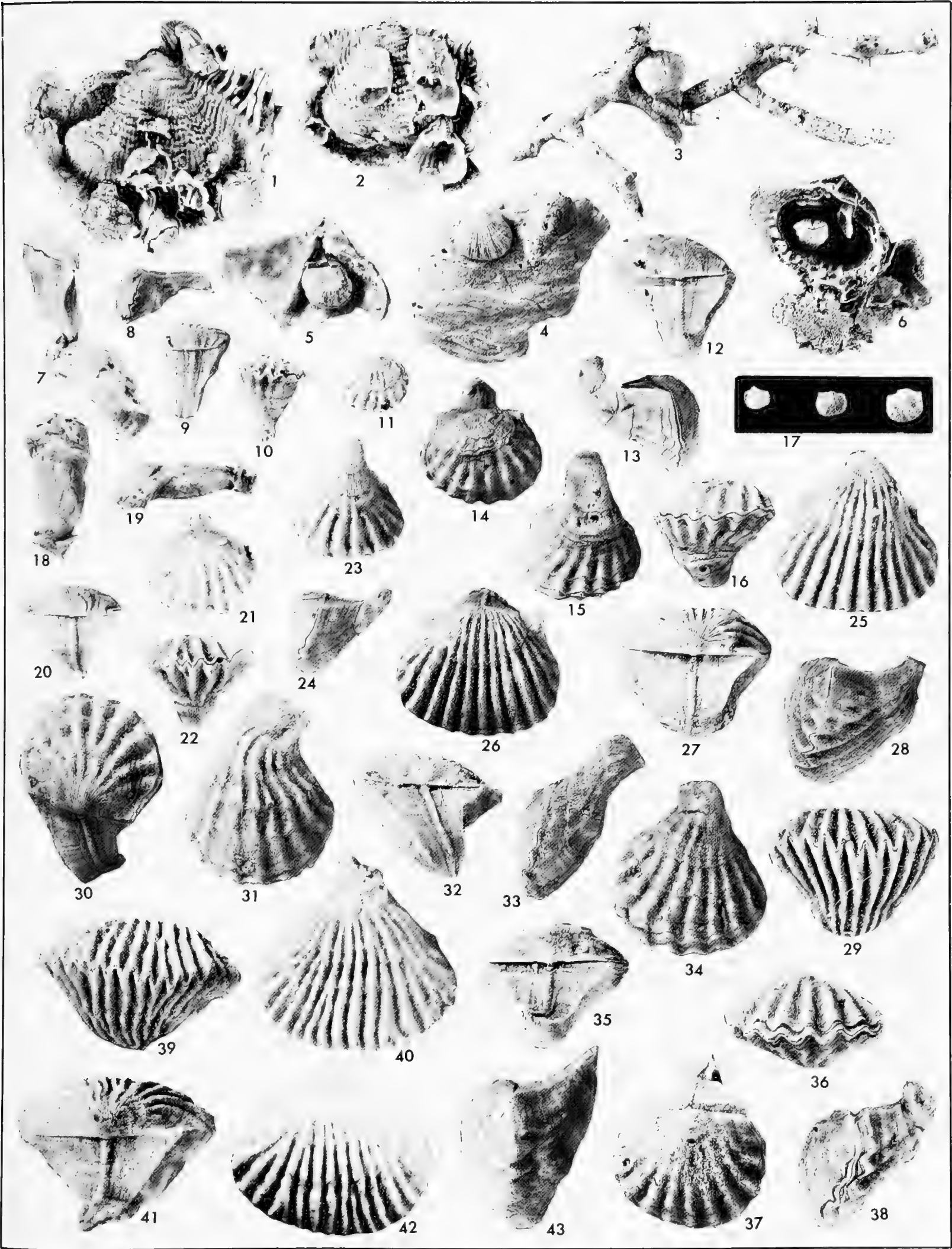
*Meekella calathica*, new species: 1, 2, Immature specimens attached to *Institella*,  $\times$  1, paratypes USNM 153527a, b [Cathedral Mountain Formation (Wedin Member), locality USNM 714w].

3, Immature individual attached in crotch of bryozoan branch,  $\times$  1, paratype USNM 153528b; 4, another immature individual attached to a lyttoniid shell,  $\times$  1, paratype USNM 153529; 6, two small individuals attached inside *Hercosia*,  $\times$  1, paratype USNM 153528a; 20–24, posterior, dorsal, anterior, ventral and side views of a small adult,  $\times$  1, paratype USNM 150605f; 39–43, anterior, ventral, posterior, dorsal, and side views of a finely costate adult,  $\times$  1, paratype USNM 150481a [Cathedral Mountain Formation, (lower), locality USNM 702].

5, Immature specimen attached in a *Derbyia* valve,  $\times$  1, paratype USNM 153520g; 7, young individual attached by its beak to a sister specimen,  $\times$  1, paratype USNM 153530; 8–11, side, posterior, anterior, and dorsal views of a young, greatly elongated specimen,  $\times$  1, paratype USNM 150910–1; 12–16, posterior, side, dorsal, ventral, and anterior views of a young adult with twisted beak,  $\times$  1, paratype USNM 150910h; 17, three immature individuals,  $\times$  1, paratypes USNM 150910r, q, p; 18, 19, ventral and side views of a greatly elongated young adult,  $\times$  1, paratype USNM 150490b; 30–33, dorsal, ventral, posterior, and side views of a flattened adult,  $\times$  1, paratype USNM 150910e [Road Canyon Formation, locality USNM 703a].

25–29, Ventral, dorsal, posterior, side, and anterior views of specimen with pronounced ears,  $\times$  1, paratype USNM 150484b; 34–38, ventral, posterior, anterior, dorsal, and side views of a specimen with strongly twisted beak,  $\times$  1, paratype USNM 150484c [Road Canyon Formation, locality USNM 702c].

PLATE 111.—*Meekella*.





## PLATE 112

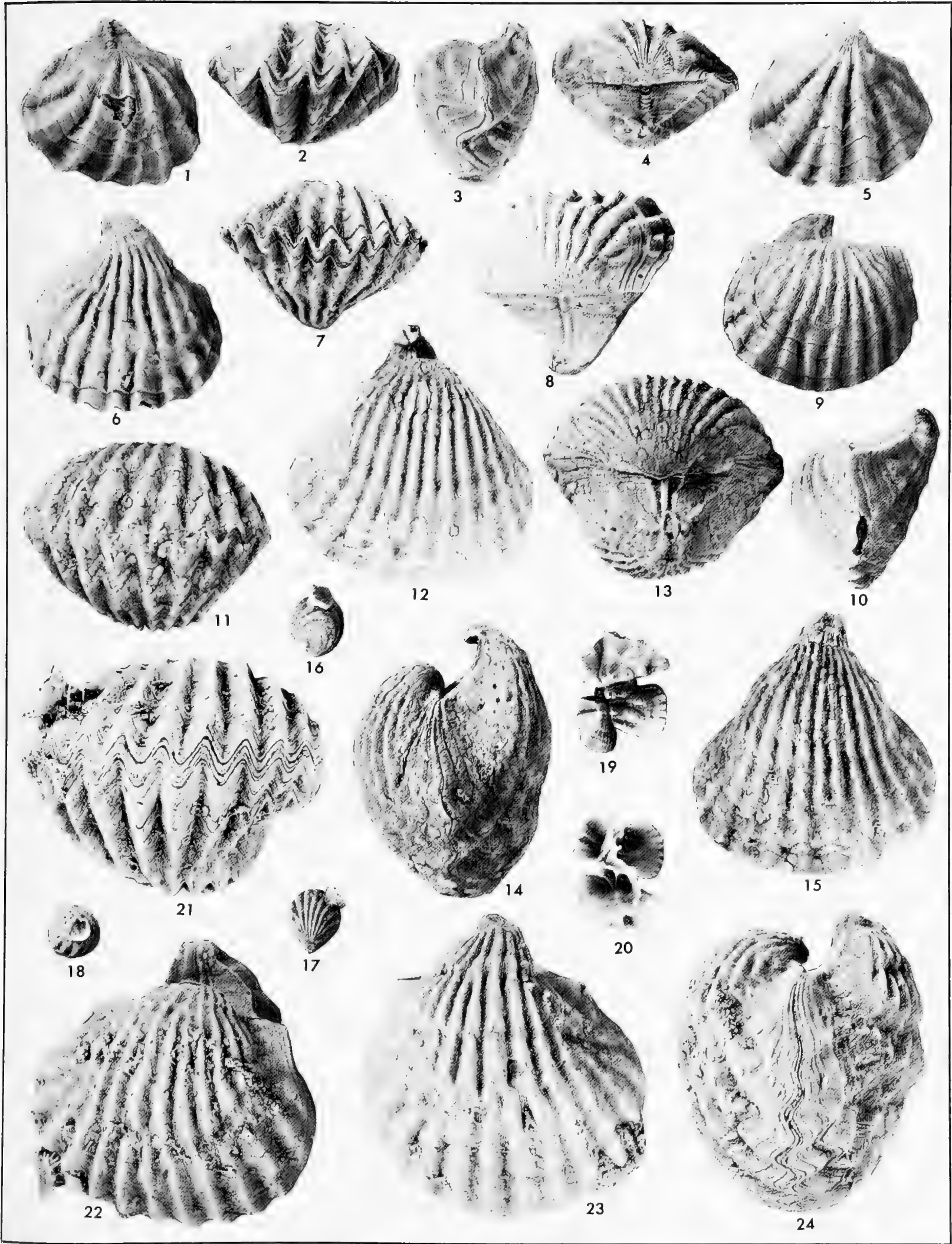
*Meekella*

*Meekella calathica*, new species: 1–5, Dorsal, anterior, side, posterior, and ventral views of a coarsely costated individual, showing costellate apex,  $\times$  1, paratype USNM 150484a; 19, 20, cluster of small pedicle valves, cemented together,  $\times$  2, paratype USNM 153523; 21–24, anterior, dorsal, ventral, and side views of a large specimen,  $\times$  1, holotype USNM 152604 [Road Canyon Formation, locality USNM 702c].

6–10, Ventral, anterior, posterior, dorsal, and side views of a less strongly costated specimen,  $\times$  1, paratype USNM 150910c; 16–18, tilted, posterior, and interior views of an immature specimen attached to *Hustedia*,  $\times$  1, paratype USNM 153520b [Road Canyon Formation, locality USNM 703a].

11–15, Anterior, dorsal, posterior, side, and ventral views of a large individual,  $\times$  1, paratype USNM 153524 [Road Canyon Formation, locality USNM 721a].

PLATE 112.—*Meekella*.



## PLATE 113

*Meekella*

*Meekella calathica*, new species: 1, Posterior of a partial specimen, showing both valves in contact and displaying the cardinal process and dental plates,  $\times$  1, paratype USNM 153520a; 2-4, anterior, interior, and laterally tilted views of a small brachial valve,  $\times$  1, paratype USNM 150490a [Road Canyon Formation, locality USNM 703a].

5-7, Interior, anterior, and laterally tilted views of the cardinalia, showing cardinal process and flanking supporting plates,  $\times$  2, paratype USNM 153521 [Road Canyon Formation, locality USNM 703d].

8-11, Anterior, dorsal, ventral, and side views of a strongly costate individual,  $\times$  1, paratype USNM 153522 [Road Canyon Formation, locality USNM 721t].

12-15, Posterior, side, dorsal, and ventral views of an unusually large and rotund specimen,  $\times$  1, paratype USNM 150909f [Road Canyon Formation, locality USNM 702c].

PLATE 113.—*Meekella*.



## PLATE 114

*Niviconia* and *Meekella*

*Niviconia globosa* R. E. King: 1-5, Dorsal, posterior, side, anterior, and ventral views of a small specimen,  $\times 1$ , hypotype USNM 150516c; 6-10, side, posterior, dorsal, anterior, and ventral views of a larger specimen,  $\times 1$ , hypotype USNM 150517a [Cathedral Mountain Formation, locality USNM 702un].

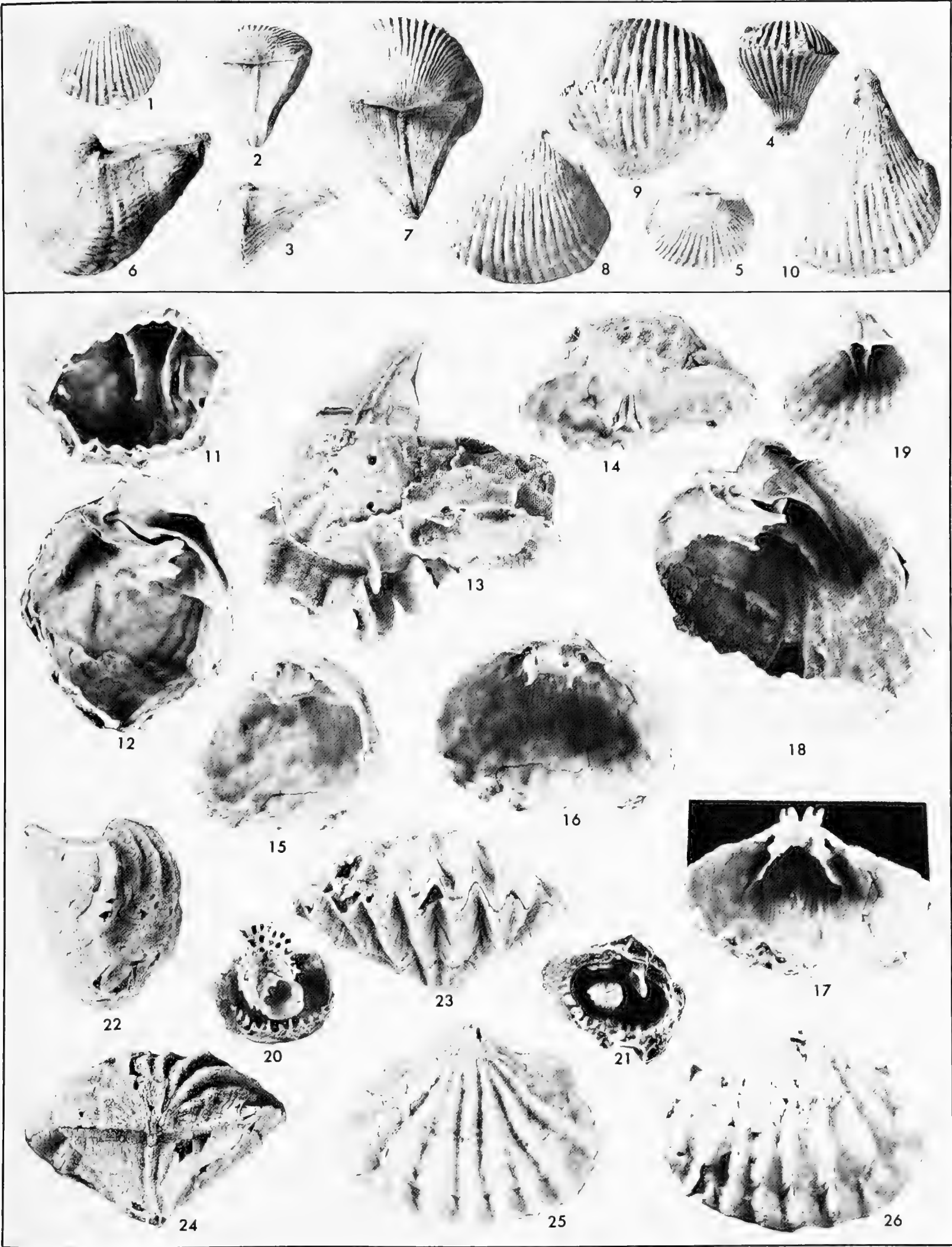
*Meekella calathica*, new species: 11, Interior of a small specimen, showing cardinal process and supporting plates,  $\times 1$ , paratype USNM 153520c; 12, a larger specimen in similar pose to preceding, showing cardinal process extending into delthyrial cavity,  $\times 1$ , paratype USNM 153520d; 14-17, posterior, laterally tilted, interior, and anterior views of a brachial valve,  $\times 1$ , paratype USNM 153520e; 19, interior of a pedicle valve, showing convergent dental plates,  $\times 1$ , paratype USNM 153520f [Road Canyon Formation, locality USNM 703a].

18, Interior of a large specimen with both valves, cardinal process, and dental plates,  $\times 1$ , paratype USNM 150481b; 20, 21, immature specimens attached to *Hercosia*,  $\times 1$ , paratypes USNM 153525a and 153528a [Cathedral Mountain Formation (lower), locality USNM 702].

13, Acuminate specimen almost engulfed by bryozoa,  $\times 1$ , paratype USNM 153526; 22-26, side, anterior, posterior, ventral, and dorsal views of a large and coarsely costate individual,  $\times 1$ , paratype USNM 150909b [Road Canyon Formation, locality USNM 702c].



PLATE 114.—*Niviconia* and *Meekella*.



## PLATE 115

*Meekella*

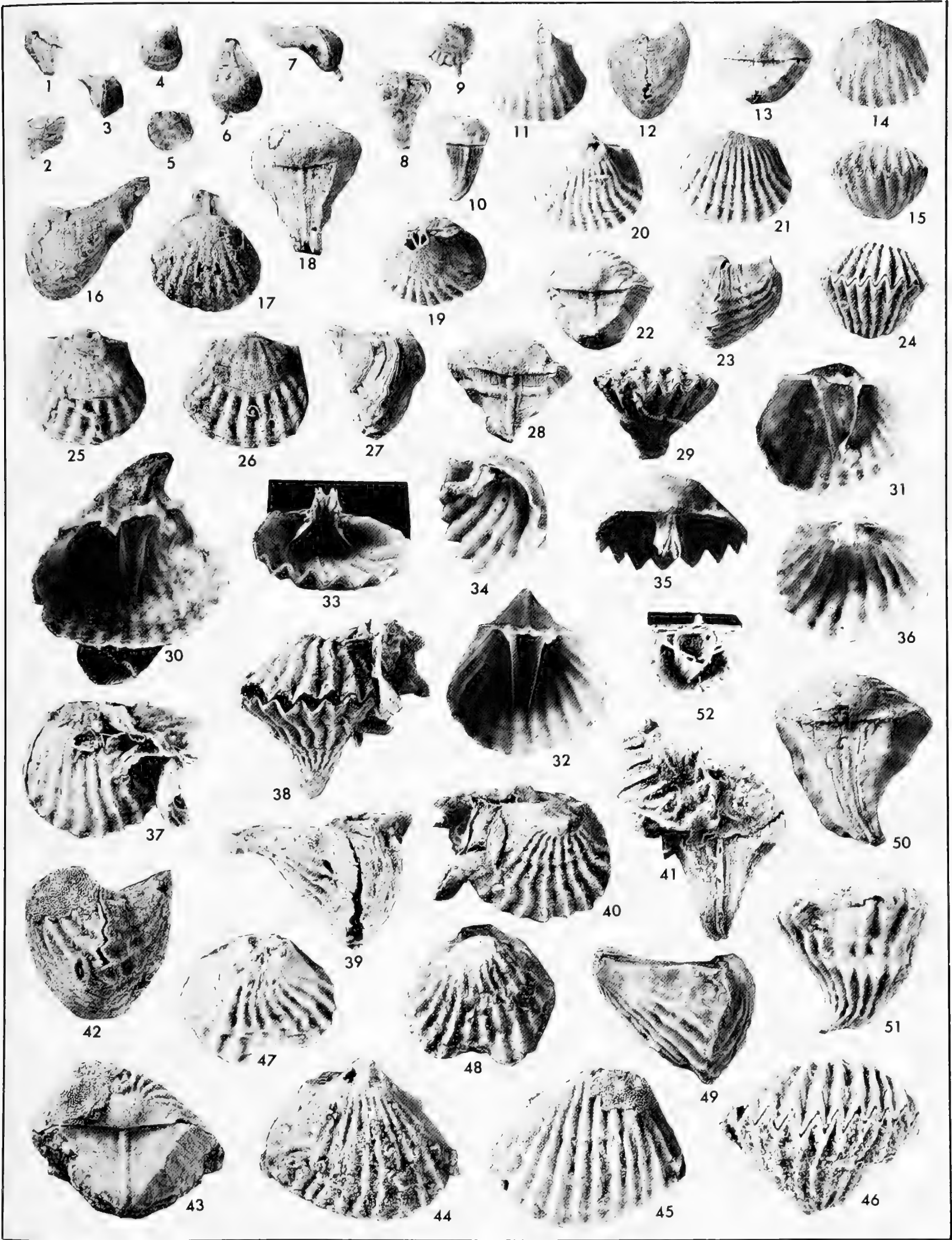
*Meekella skenoides* Girty: 1–5, Posterior, anterior, side, ventral, and dorsal views of an immature individual, showing early costellate ornament  $\times 1$ , hypotype USNM 153542a; 6–10, dorsal, side, anterior, ventral, and posterior views of a young but elongated specimen, showing the beginning of costae at the anterior,  $\times 1$ , hypotype USNM 153542b; 11–15, ventral, side, posterior, dorsal, and anterior view of a small adult,  $\times 1$ , hypotype USNM 153542c; 16–19, side, dorsal, posterior, and ventral views of a small adult with elongated beak,  $\times 1$ , hypotype USNM 153542d; 30–32, interior of three pedicle valves, showing dental plates,  $\times 1$ , hypotypes USNM 153542g, i; 33–36, anterior, laterally tilted, posterior, and interior views of the brachial valve,  $\times 1$ , hypotype USNM 153542j; 37–41, dorsal, anterior, side, ventral, and posterior views of an elongated specimen partially covered by lyttoniaceans,  $\times 1$ , hypotype USNM 153542e; 42–46, side, posterior, ventral, dorsal, and anterior views of a large adult,  $\times 1$ , hypotype USNM 153542f; 52, immature attached specimen aborted by spines of *Echinauris*,  $\times 1$ , hypotype USNM 153542k [Word Formation (Willis Ranch Member), locality USNM 706e].

20–24, Ventral, dorsal, posterior, side, and anterior views of a small adult,  $\times 1$ , hypotype USNM 153534a; 32, interior of the pedicle valve, showing the dental plates,  $\times 1$ , hypotype USNM 153534c [lens between the Willis Ranch and Appel Ranch Members, locality USNM 706b].

25–29, Ventral, dorsal, side, posterior, and anterior views of a small adult,  $\times 1$ , hypotype USNM 150544e [Cherry Canyon Formation (Getaway Member), locality USNM 728].

47–51, Ventral, dorsal, side, posterior, and anterior views of an elongated adult,  $\times 1$ , hypotype USNM 150949a [Carlsbad Formation, locality USGS 7417].

PLATE 115.—*Meekella*.



## PLATE 116

*Meekella*

*Meekella skenoides* Girty: 1, Specimen of *Paucispinifera* with young *Meekella skenoides* attached,  $\times 1$ , hypotype USNM 150559a; 2, part of preceding specimen enlarged,  $\times 2$ ; 3, specimen of *Collemataria* with several immature *Meekella skenoides* attached,  $\times 1$ , hypotype USNM 150559b; 4, the preceding enlarged,  $\times 2$ ; 5, part of dorsal valve of *Collemataria* with two attached *Meekella skenoides*,  $\times 3$ , hypotype USNM 150559c; 7, two immature specimens attached to the brachial valve of *Echinauris*,  $\times 1$ , hypotype USNM 150559d [Word Formation (Willis Ranch Member), locality USNM 706e].

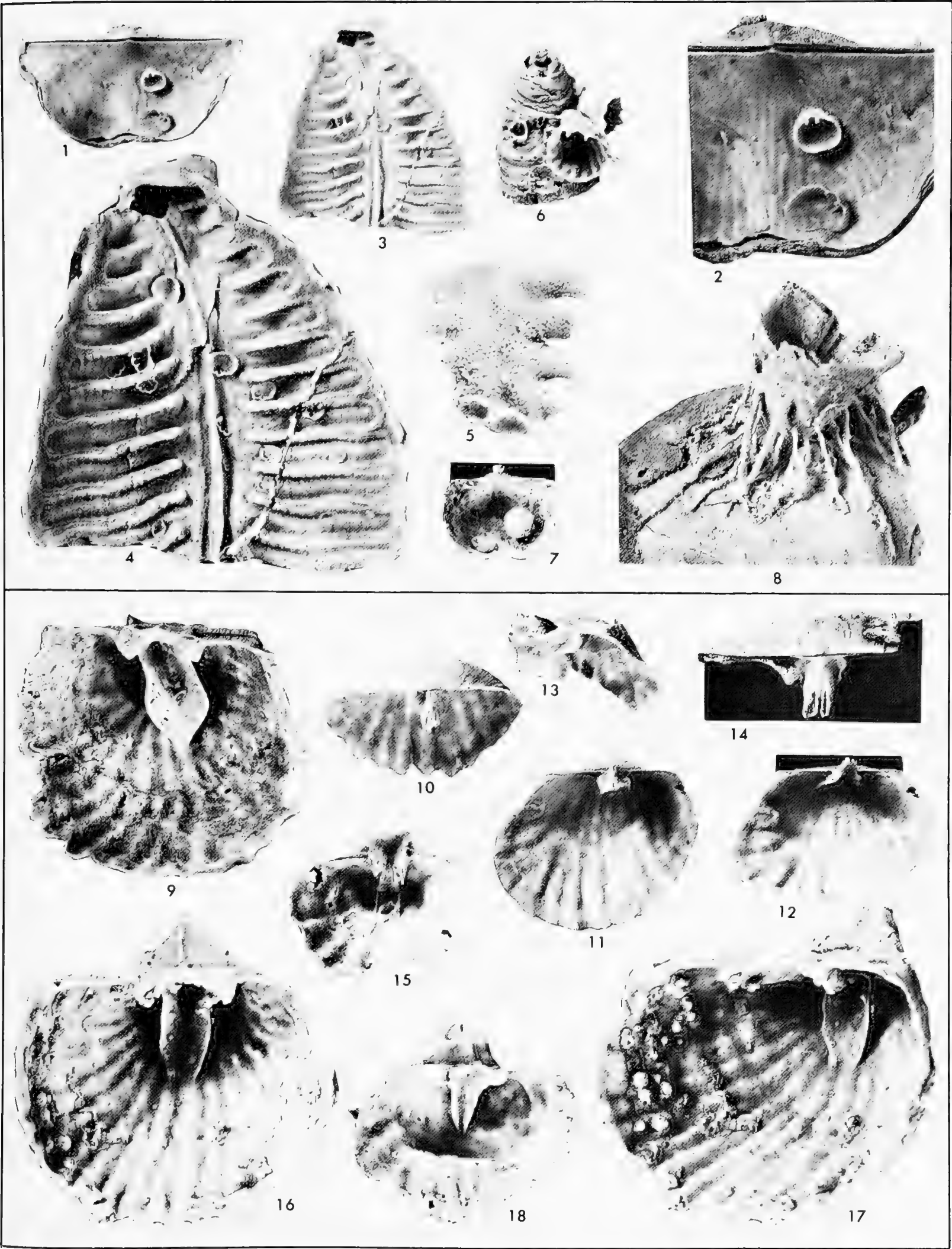
6, Two immature individuals attached to *Cyclacantharia*,  $\times 1$ , hypotype USNM 153537 [Word Formation (China Tank Member), locality USNM 706c].

8, Small *Meekella skenoides* imprisoned by the spines of *Cyclacantharia*,  $\times 2$ , hypotype USNM 150820 [Word Formation (Willis Ranch Member), locality USNM 706e].

*Meekella magnifica*, new species: 9, Interior of a large pedicle valve, showing dental plates converging to form a chamber attached to the valve floor,  $\times 1$ , paratype USNM 153535a; 10–12, posterior, interior, and anterior views of a brachial valve,  $\times 1$ , paratype USNM 153535f; 13, 14, partial side and posterior views of a large cardinal process,  $\times 1$ , paratype USNM 150577; 15, interior of a small specimen, showing cardinalia and a blister between the dental plates caused by a boring,  $\times 1$ , paratype USNM 153535g; 16, 17, interior of a large pedicle valve,  $\times 1$ , paratype USNM 153535b; 18, interior of a smaller pedicle valve,  $\times 1$ , paratype USNM 153535c [Neal Ranch Formation (bed 9 of Cooper=bed 12 of P. B. King), locality USNM 701g].



PLATE 116.—*Meekella*.





## PLATE 117

*Meekella* and *Enteleles*

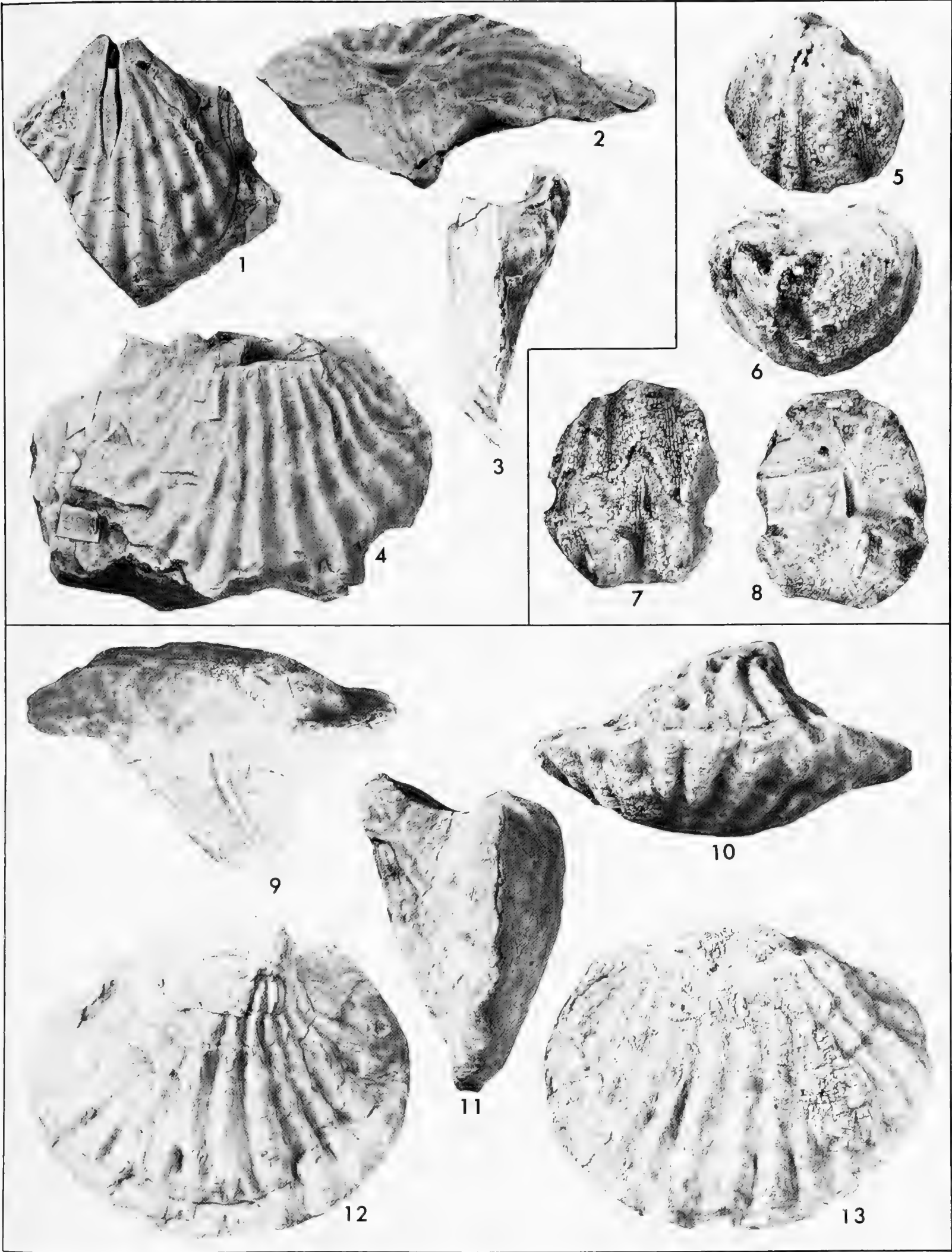
*Meekella occidentalis* (Newberry): 1, Internal mold of a pedicle valve, showing slits representing dental plates,  $\times$  1, holotype USNM 92468 [Permian, Camp 73 in canyon of Cascade River, Arizona].

2-4, Posterior, side, and dorsal views of a large, crushed individual,  $\times$  1, paratype USNM 92469 [Permian, Canyon of Diamond River, Arizona].

*Enteleles globosus* Girty: 5-8, Ventral, side, anterior, and posterior views of the holotype,  $\times$  2, USNM 118551 [Delaware Mountain Formation, locality USGS 3763 (green)].

*Meekella grandis* R. E. King: 9-13, Posterior, anterior, side, ventral, and dorsal views of the holotype,  $\times$  1, YPM 10589 [Cathedral Mountain Formation (upper), locality R. E. King 174].

PLATE 117.—*Meekella* and *Enteletes*.



## PLATE 118

*Meekella*, *Bothrostegium*, and *Niviconia*

*Meekella texana* R. E. King; 1-3, Side, ventral, and posterior view of an immature and imperfect pedicle valve,  $\times 1$ , holotype YPM 10966 [Gaptank Formation (*Uddenites*-bearing Shale Member), locality R. E. King 199].

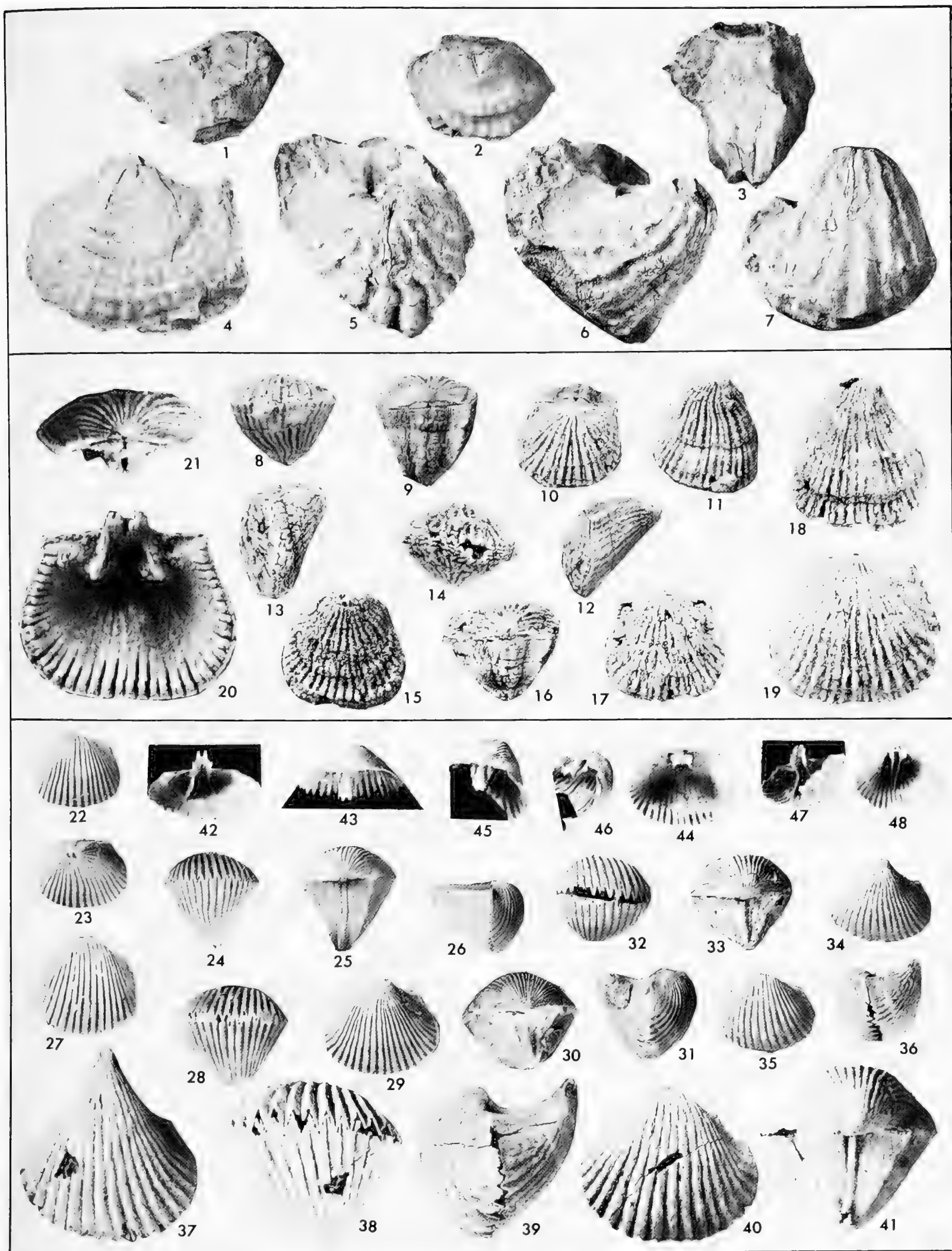
4, Exterior of an exfoliated brachial valve,  $\times 1$ , paratype YPM 10967 [Gaptank Formation (*Uddenites*-bearing Shale Member), locality R. E. King 95].

5-7, Ventral, side, and anterior views of another imperfect pedicle valve,  $\times 1$ , paratype YPM 10968 [Gaptank Formation (*Uddenites*-bearing Shale Member), locality R. E. King (Schuchert) 88s].

*Bothrostegium pusillum*, new species: 8-12, Anterior, posterior, dorsal, ventral, and side views of the holotype  $\times 4$ , USNM 152594a; 13-17, side, anterior, ventral, posterior, and dorsal views of another complete specimen,  $\times 4$ , paratype USNM 152594b; 18, exterior of a large pedicle valve,  $\times 4$ , paratype USNM 152594e; 19, exterior of a brachial valve,  $\times 4$ , paratype USNM 152594n; 20, interior of the same specimen, showing the cardinalia,  $\times 5$ ; 21, posterior of another brachial valve, showing the cardinal process,  $\times 4$ , paratype USNM 152594j [Road Canyon Formation, locality USNM 722e].

*Niviconia abrupta*, new species: 22-26, Dorsal, ventral, anterior, posterior, and side views of a small specimen,  $\times 1$ , paratype USNM 153540a; 27-31, dorsal, anterior, ventral, posterior, and side views of another individual larger than the preceding,  $\times 1$ , paratype USNM 153540b; 32-36, anterior, posterior, ventral, dorsal, and side views of a small paratype,  $\times 1$ , USNM 150512e; 37-41, ventral, anterior, side, dorsal, and posterior views of a large specimen,  $\times 1$ , holotype USNM 150512f; 42-44, anterior, posterior, and interior views of a brachial valve,  $\times 1$ , paratype USNM 153540c; 45-47, posterior, laterally tilted, and anterior views of an imperfect brachial valve, showing cardinal process,  $\times 1$ , paratype USNM 153540d; 48, interior of the pedicle valve,  $\times 1$ , paratype USNM 153540e [Cathedral Mountain Formation (middle), locality USNM 702a].

should be  
N. gibbosa?

PLATE 118.—*Meekella*, *Bothrostegium*, and *Niviconia*.

## PLATE 119

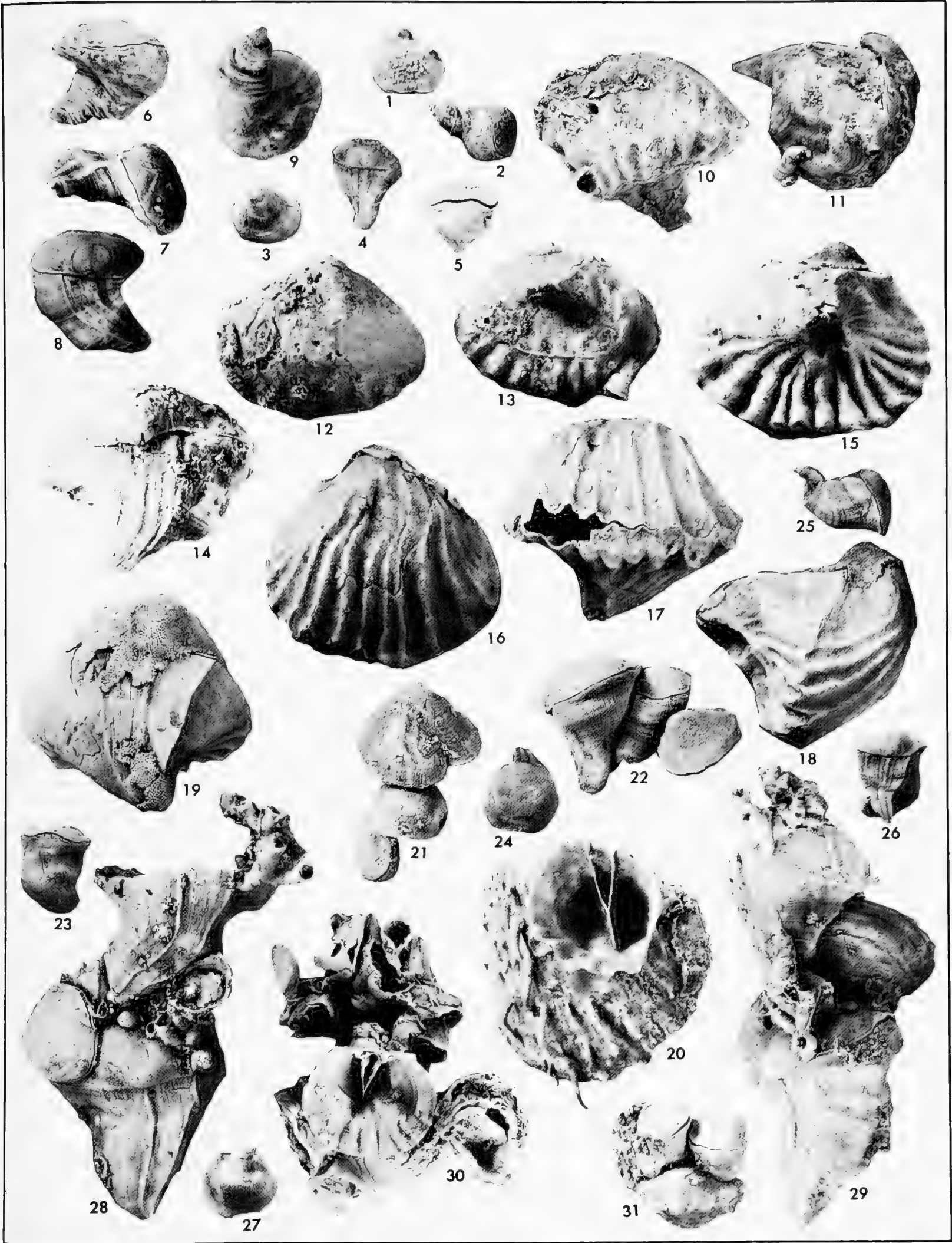
*Geyerella*

*Geyerella kingorum*, new species: 1–5, Dorsal, side, ventral, posterior, and anterior views of a small individual,  $\times 1$ , paratype USNM 150970e; 6–9, anterior, side, posterior, and ventral views of a larger and distorted specimen,  $\times 1$ , paratype USNM 153510g; 15–19, ventral, dorsal, anterior, side, and posterior views of an exceptionally large specimen,  $\times 1$ , holotype USNM 150970o; 20, pedicle valve attached to a large, spiny pelecypod,  $\times 1$ , paratype USNM 153510h; 21, 22, cluster of three attached specimens,  $\times 1$ , paratype USNM 153510i; 23–27, anterior, dorsal, side, posterior, and ventral views of a small specimen with aborted and distorted beak,  $\times 1$ , paratype USNM 153510j; 28, 29, posterior and side views of a cluster of attached individuals,  $\times 1$ , paratype USNM 150969; 30, another cluster, showing pedicle valve interior  $\times 1$ , paratype USNM 153510k; 31, a cluster of small specimens,  $\times 1$ , paratype USNM 153510–1 [Neal Ranch Formation, locality, USNM 7011].

10–14, Anterior, side, dorsal, ventral, and posterior views of a large specimen with aborted and distorted beak,  $\times 1$ , paratype USNM 150968b [Neal Ranch Formation, locality USNM 701h].



PLATE 119.—*Geyerella*.



## PLATE 120

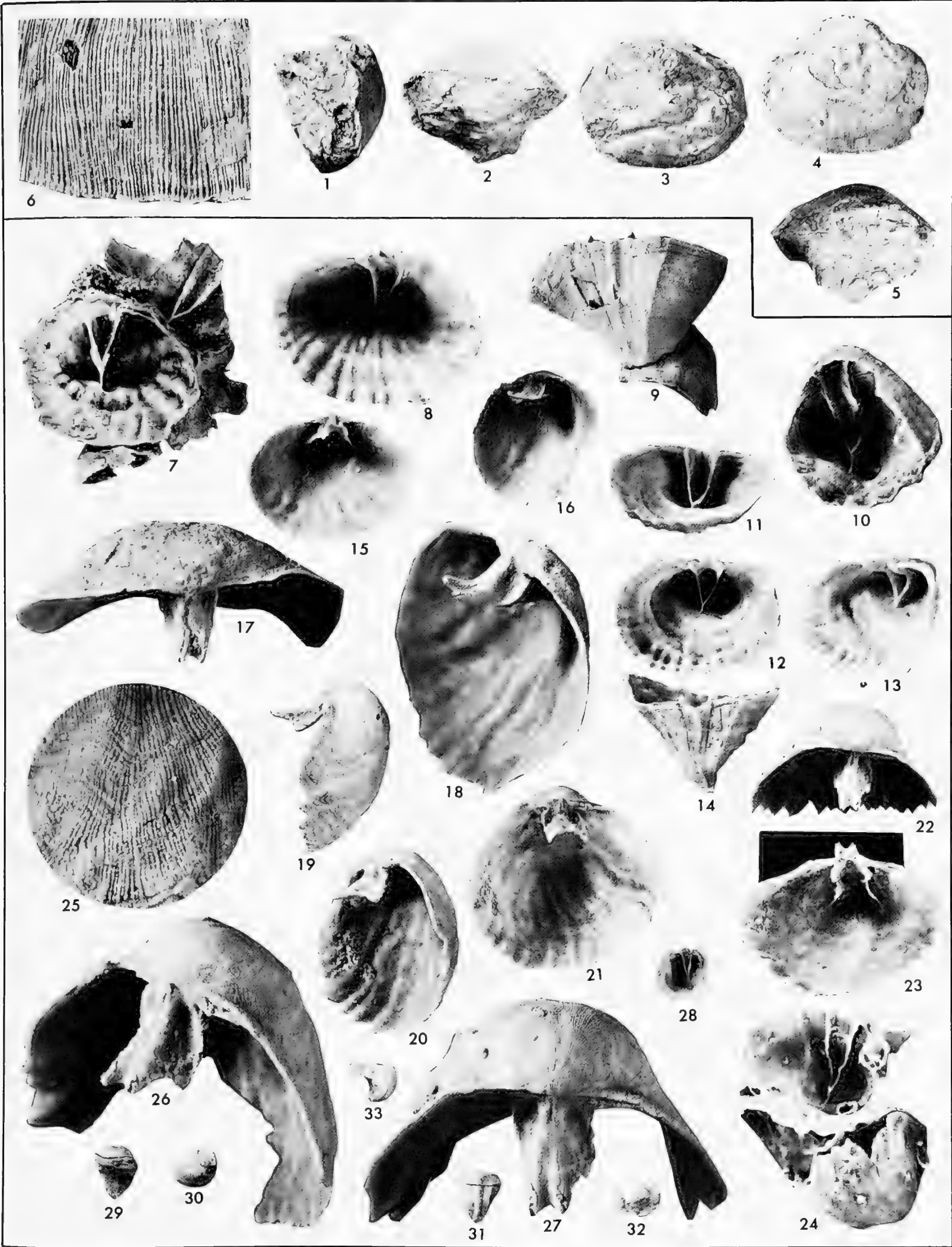
*Geyerella*

*Geyerella kingorum*, new species (= *Orthotetina* species, R. E. King): 1–5 Side, anterior, ventral, dorsal, and posterior views of King's specimen, showing only incipient costation,  $\times$  1, figured specimen YPM 11420; 6, ornament of the preceding,  $\times$  4 [Neal Ranch Formation, locality R. E. King 91].

*Geyerella kingorum*, new species: 7, Interior of the pedicle valve, showing the spondylium,  $\times$  1, paratype USNM 153509 [Neal Ranch Formation, locality USNM 701h].

8, 9, Interior and posterior of a large pedicle valve, showing spondylium and interarea with pseudodeltidium and elevated monticulus,  $\times$  1, paratype USNM 153510a; 10, interior of a broken specimen, showing cardinal process and spondylium,  $\times$  1, paratype USNM 153510b; 11–14, posteriorly tilted, interior, laterally tilted and posterior views of another pedicle valve,  $\times$  1, paratype USNM 153510c; 15, 16, interior and laterally titled views of a brachial valve,  $\times$  1, paratype USNM 153510d; 17, 18, posterior and posterolateral views of the preceding specimen, showing cardinal process and promontorium,  $\times$  2; 19–23, side, laterally tilted, interior, posterior, and interior tilted views of another brachial valve, showing the cardinal process,  $\times$  1, paratype USNM 153510e; 24, interior of an attached pedicle valve,  $\times$  1, paratype USNM 155104; 25, exterior of the preceding, showing details of the ornament,  $\times$  4; 26, 27, posterolateral and posterior views of the same specimen, showing the cardinal process in detail,  $\times$  2; 28, interior of an immature pedicle valve, showing well-formed spondylium,  $\times$  1, paratype USNM 153510f; 29–33, anterior, dorsal, posterior, ventral, and side views of a complete but immature specimen  $\times$  1, paratype USNM 150970c [Neal Ranch Formation, locality USNM 701k].

PLATE 120.—*Geyerella*.



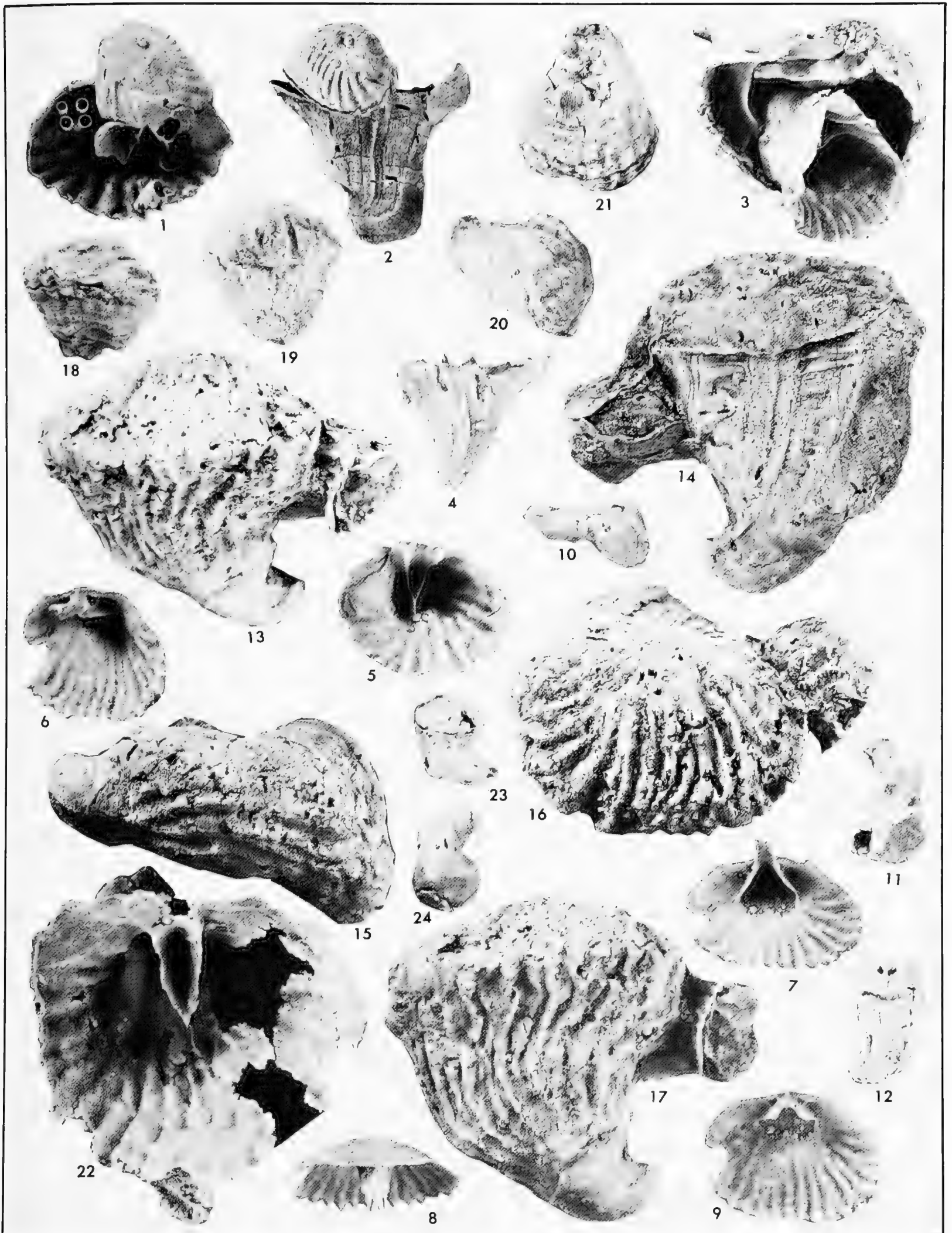
## PLATE 121

*Geyerella*

*Geyerella hessi*, new species: 1, 2, Pedicle valve with attached complete individual,  $\times$  1, paratype USNM 153508g; 3, specimen occupying the living cavity of a large specimen,  $\times$  1, paratype USNM 153508f; 4, 5, posterior and interior of a pedicle valve, showing spondylium,  $\times$  1, paratype USNM 153508e; 6–9, laterally tilted, posteriorly tilted, posterior, and interior views of a brachial valve,  $\times$  1, paratype USNM 153508d; 10–12, side, anterior, and posterior views of an immature but much elongated specimen,  $\times$  1, paratype USNM 153508h; 13–17, anterior, posterior, side, dorsal, and anterior views of a large, silicified specimen,  $\times$  1, paratype USNM 153508i [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].

18–21, Anterior, posterior, side, and ventral views of a small specimen,  $\times$  1, paratype USNM 150975c; 22, interior of a large pedicle valve, showing the spondylium,  $\times$  1, paratype USNM 150974, 23, 24, posterior and anterior views of a small distorted specimen,  $\times$  1, paratype USNM 150975a [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].



PLATE 121.—*Geyerella*.

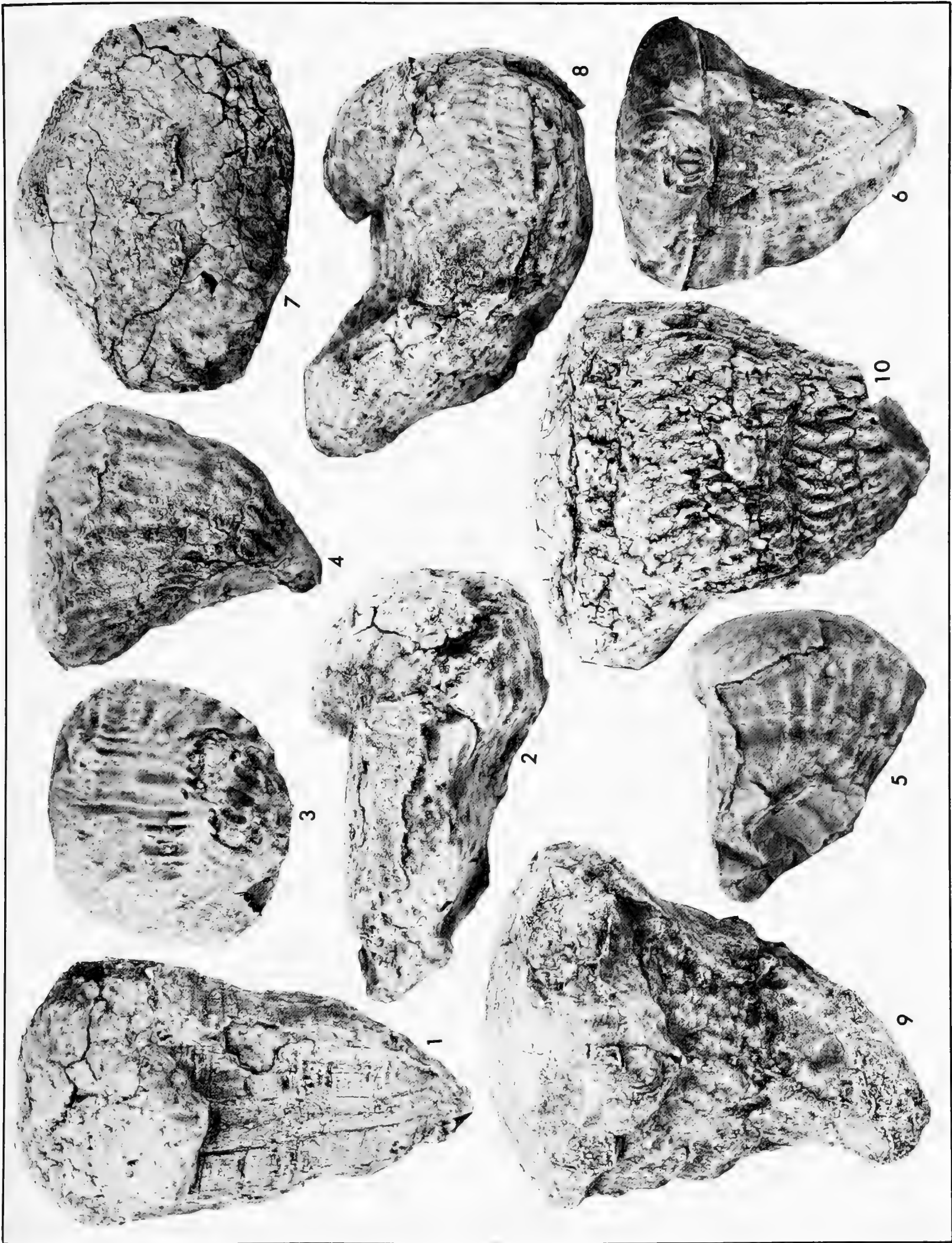


## PLATE 122

*Geyerella*

*Geyerella hessi*, new species: 1, 2, Posterior and side views of an elongated specimen,  $\times 1$ , paratype USNM 152605b; 3-6, dorsal, anterior, side, and posterior views of a smaller, more triangular specimen,  $\times 1$ , paratype USNM 150975g; 7-10, dorsal, side, posterior, and anterior views of a large specimen,  $\times 1$ , paratype USNM 150975j [Skinner Ranch Formation (Decie Ranch Member), locality USMN 707a].

PLATE 122.—*Geyerella*.



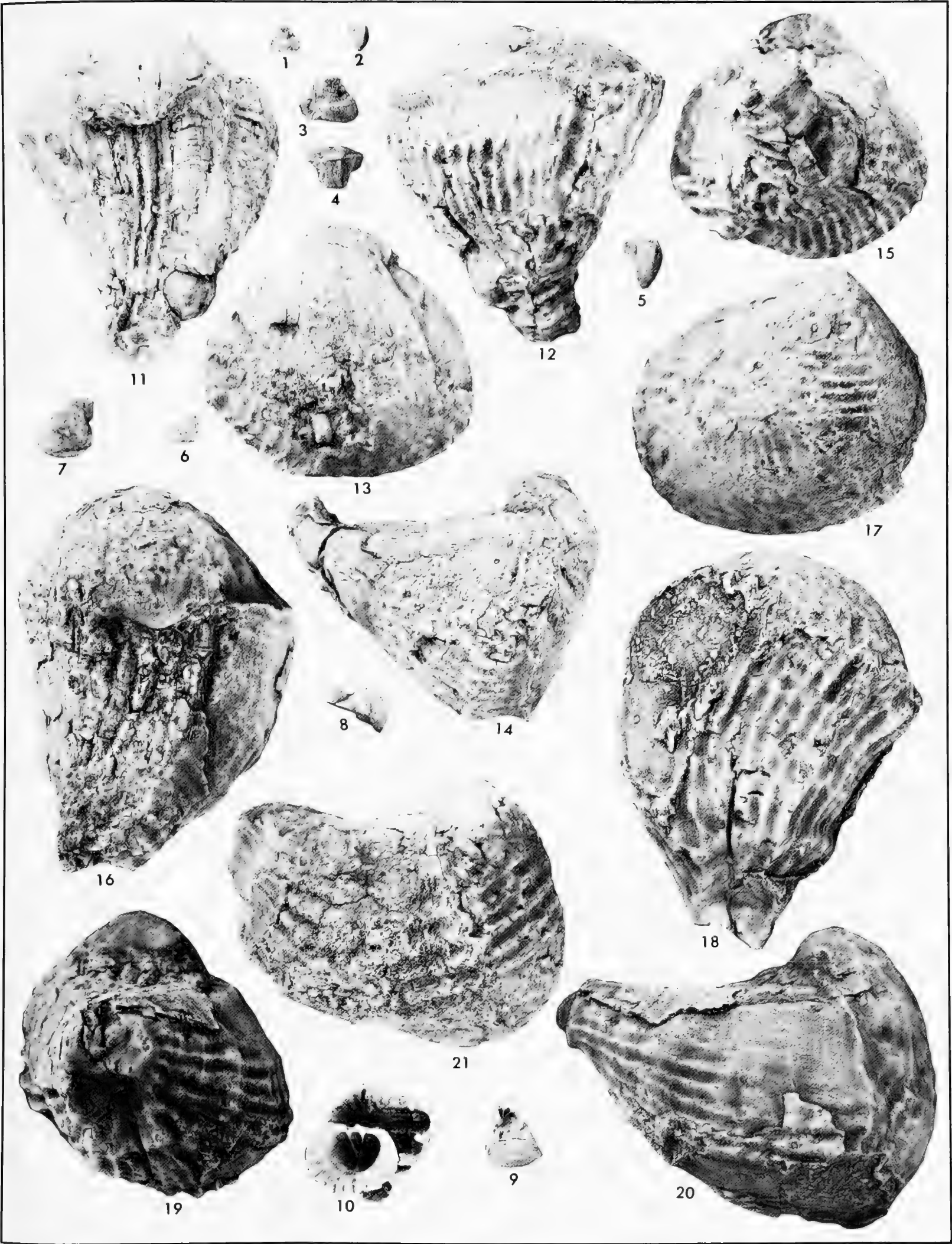
## PLATE 123

*Geyerella*

*Geyerella hessi*, new species: 1, 2, Ventral and side views of an immature specimen,  $\times 1$ , paratype USNM 153508a; 3-5, ventral, posterior, and side views of the same specimen,  $\times 2$ ; 6-9, ventral,  $\times 1$ ,  $\times 2$ , side and posterior views,  $\times 2$ , of an immature but larger specimen than the preceding, paratype USNM 153508b; 10, interior of a small pedicle valve, showing the spondylium,  $\times 1$ , paratype USNM 153508c [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].

11-15, Posterior, anterior, dorsal, side, and ventral views of an adult,  $\times 1$ , paratype USNM 152605c; 16-20, posterior, dorsal, anterior, ventral, and side views of the holotype,  $\times 1$ , USNM 152605a; 21, side view of a stout specimen, showing attachment surface at beak,  $\times 1$ , paratype USNM 147735a [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

PLATE 123.—*Geyerella*.



## PLATE 124

*Geyerella, Tropidelasma, and Meekella*

*Geyerella kingorum*, new species: 1–5, Anterior, ventral, dorsal, posterior, and side views of the paratype,  $\times 1$ , USNM 153830a; 6, exterior of the preceding pedicle valve to show ornament,  $\times 2$ ; 7, posterior view of a young specimen,  $\times 1$ , paratype USNM 153830b; 8, 9, posterior and interior views of a pedicle valve,  $\times 1$ , paratype USNM 153830c; 10, posterior of the brachial valve, showing the large cardinal process,  $\times 1$ , paratype USNM 153830d [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].

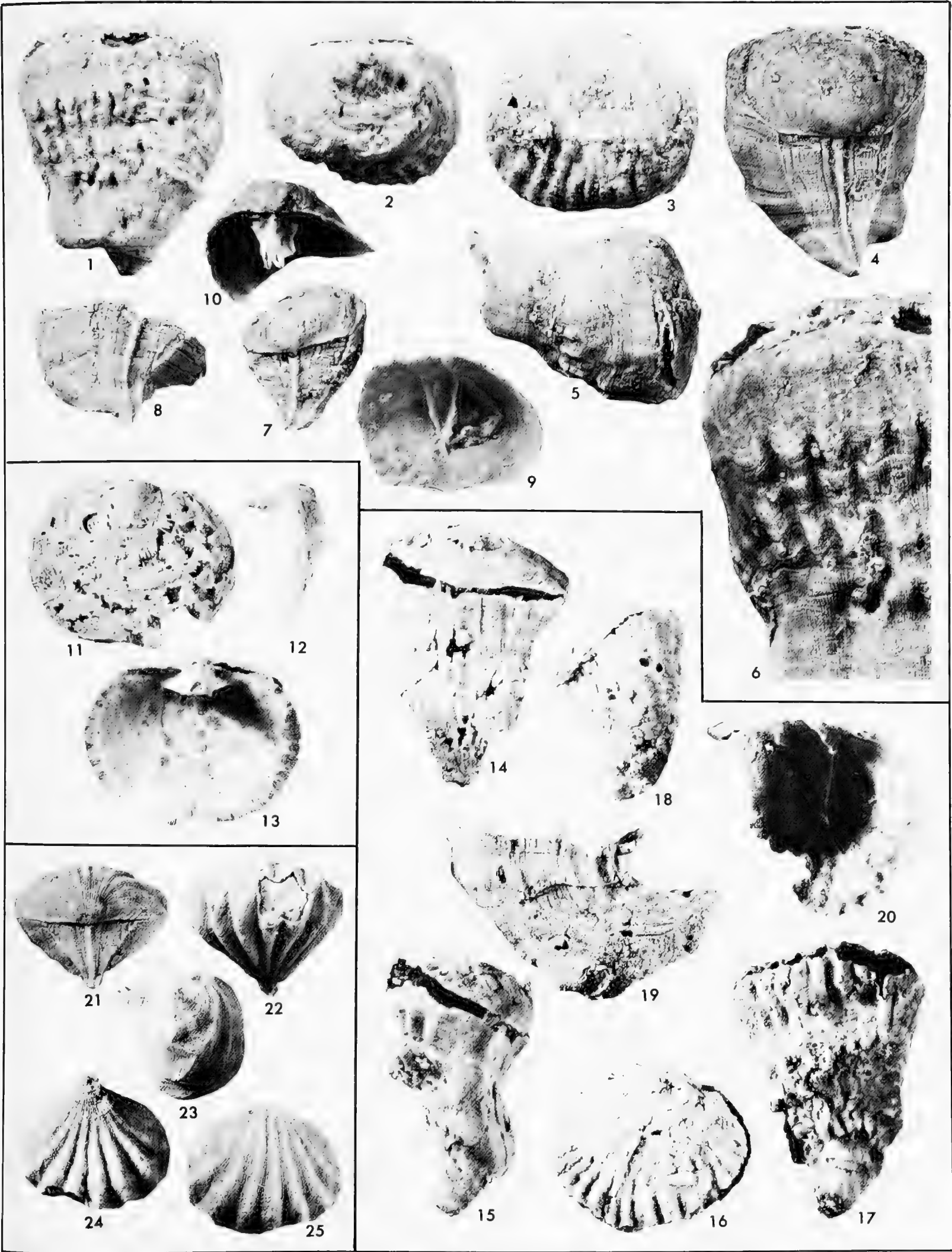
*Tropidelasma* species 4: 11–13, Exterior, side, and interior views of a large brachial valve with borings on the exterior,  $\times 1$ , figured specimen USNM 153829 [Cathedral Mountain Formation, locality USNM 721u].

*Geyerella hessi*, new species: 14–17, Posterior, side, dorsal, and anterior views of a complete specimen,  $\times 1$ , paratype USNM 150982a; 18, side view of a small complete specimen,  $\times 1$ , paratype USNM 150982b; 19, 20, posterior and interior views of a twisted individual, showing broad interarea and spondylium,  $\times 1$ , paratype USNM 150982c [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 714y].

*Meekella prionota*, new species: 21–25, Posterior, anterior, side, ventral, and dorsal views of the holotype USNM 153339 [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].



PLATE 124.—*Geyerella*, *Tropidelasma*, and *Meekella*.



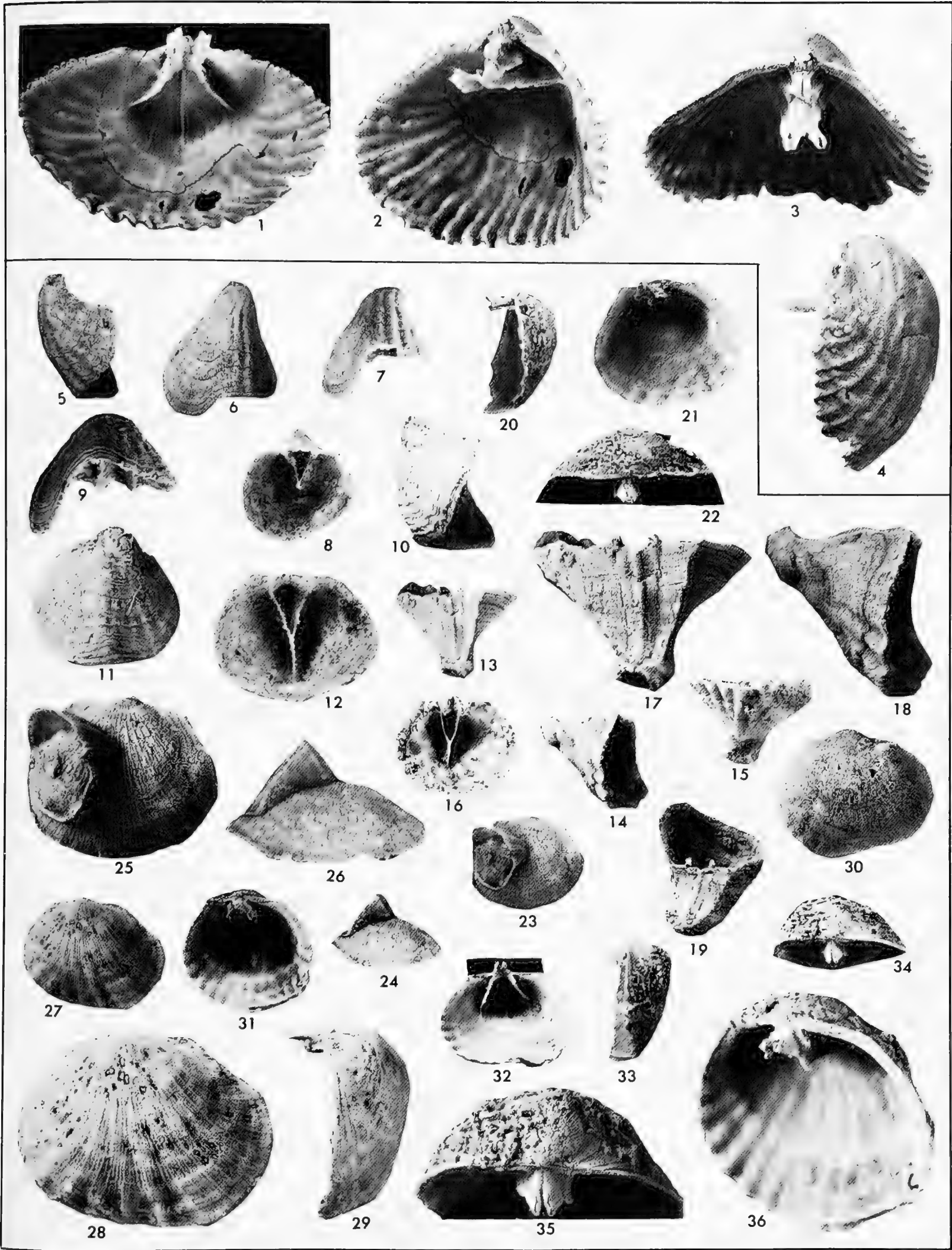
## PLATE 125

*Geyerella*

*Geyerella americana* Girty: 1-4, Posteriorly tilted, laterally tilted, posterior, and side views of an exceptional brachial valve, showing cardinal process with its modified chilidial structure,  $\times 1$ , hypotype USNM 150990 [Bell Canyon Formation (Lamar Member), locality AMNH 384].

*Geyerella inexpectata*, new species: 5-8, Side, ventral, anterior, and interior views of an eccentric pedicle valve,  $\times 1$ , paratype USNM 150986b; 9-12, anterior, side, ventral, and interior views of a specimen larger than the preceding, showing spondylium,  $\times 1$ , holotype USNM 150986e; 13-16, posterior, side, anterior and interior of another pedicle valve with strong costae,  $\times 1$ , paratype USNM 150986a; 17, 18, posterior and side views of the preceding enlarged,  $\times 2$ ; 19, posterior of another pedicle valve,  $\times 1$ , paratype USNM 150986c; 20-22, side, laterally tilted, and posterior views of brachial valve,  $\times 1$ , paratype USNM 150986g; 23, 24, small brachial valve with adherent pedicle valve of another individual,  $\times 1$ , paratype USNM 150986k; 25, 26, same,  $\times 2$ ; 27-29, dorsal,  $\times 1$ , dorsal and side,  $\times 2$ , showing ornament, hypotype USNM 150986-1; 30, exterior of another brachial valve,  $\times 1$ , paratype USNM 150986m; 31-34, laterally tilted, interior, side, and posterior views of a brachial valve,  $\times 1$ , paratype USNM 150986i; 35, 36, posterior and laterally tilted views of the preceding specimen, showing details of cardinal process,  $\times 2$  [Road Canyon Formation, locality USNM 720d].

PLATE 125.—*Geyerella*.



## PLATE 126

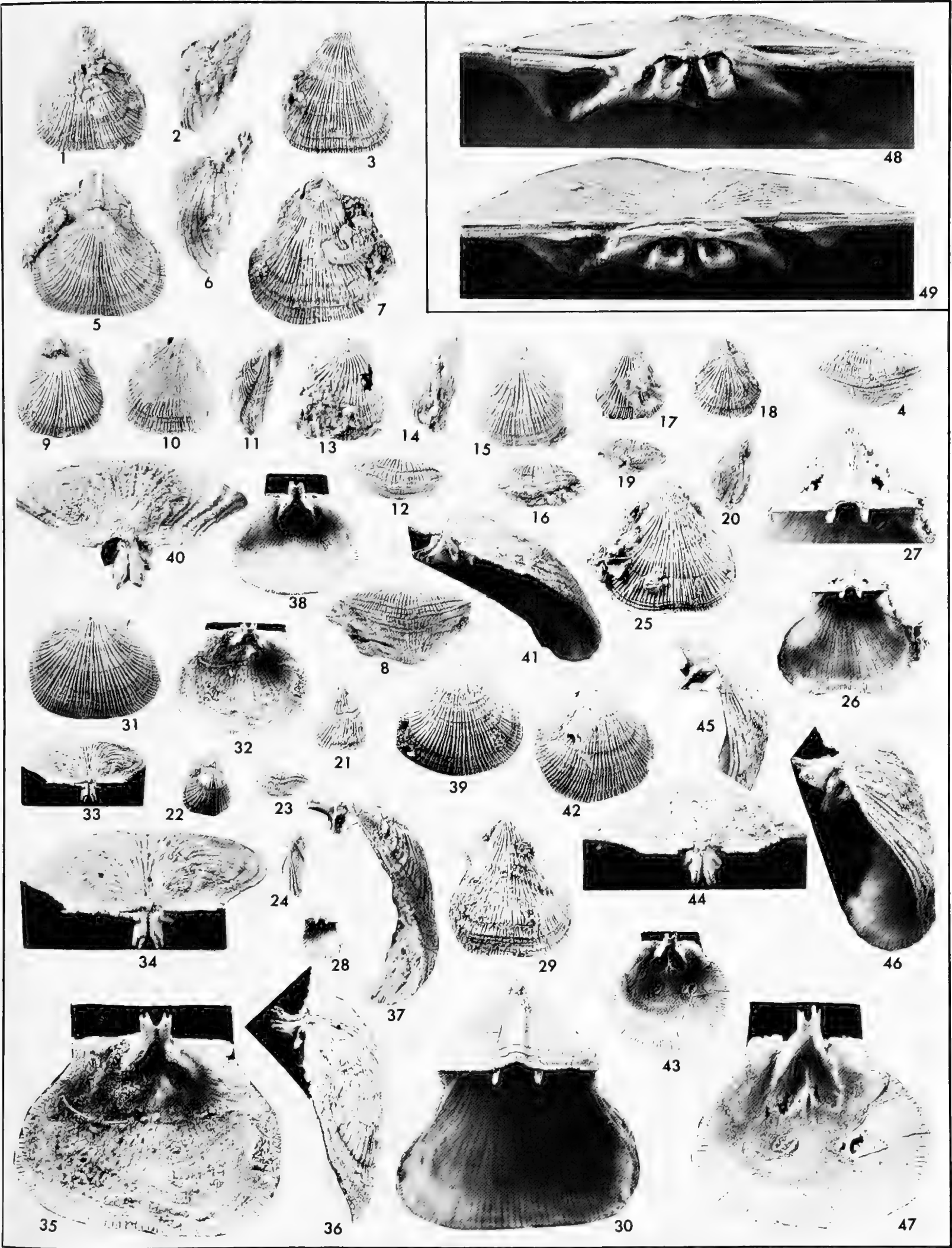
*Chelononia* and *Derbyoides*

*Chelononia neali*, new species: 1-4, Dorsal, side, ventral, and anterior views of a complete specimen,  $\times 1$ , paratype USNM 152646g; 5-8, dorsal, side, ventral, and anterior views of a large specimen,  $\times 1$ , holotype USNM 152646f; 9-12, dorsal, ventral, side, and anterior views of a young specimen,  $\times 1$ , paratype USNM 152646d; 13-16, ventral, side, dorsal, and anterior views of another small adult,  $\times 1$ , paratype USNM 152646e; 17-20, ventral, dorsal, anterior, and side views of an immature specimen,  $\times 1$ , paratype USNM 152646b; 21-24, ventral, dorsal, anterior, and side views of another immature specimen,  $\times 1$ , paratype USNM 152646a; 25, 26, exterior and interior of a pedicle valve,  $\times 1$ , paratype USNM 152646i; 27, interarea of the preceding specimen,  $\times 2$ ; 28, interior of an immature pedicle valve,  $\times 1$ , paratype USNM 152646h; 29, 30, exterior,  $\times 1$ , and interior,  $\times 2$ , of a pedicle valve, paratype USNM 152646j; 31-33, exterior, interior, and posterior views of a brachial valve,  $\times 1$ , paratype USNM 152646k; 34-37, posterior, interior, partially tilted, and side views of the preceding specimen,  $\times 1$ ; 38-41, interior and exterior of another brachial valve,  $\times 1$ , and posterior and tilted views,  $\times 2$ , paratype USNM 152646m; 42, 43, exterior and interior of a brachial valve,  $\times 1$ , paratype USNM 152646-1; 44-47, posterior, side, partial side, and interior of the preceding specimen, showing cardinalia,  $\times 2$  [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].

*Derbyoides nebrascensis* Dunbar and Condra: 48, Posterior of the brachial valve, showing the myophore and sockets,  $\times 3$ , hypotype USNM 150427e; 49, posterior of another brachial valve, showing cardinal process and chilidium,  $\times 3$ , hypotype USNM 150427h [shale just below the Cass Limestone, locality USNM 519].



PLATE 126.—*Chelononia* and *Derbyoides*.





## PLATE 127

*Pseudoleptodus* and *Poikilosakos*

*Pseudoleptodus nodosus*, new species: 1, Interior of a pedicle valve, showing few lateral lobes and the oblique, somewhat tubular, muscle attachment,  $\times 2$ , holotype USNM 150707 [Road Canyon Formation, locality USNM 713].

*Pseudoleptodus annosus*, new species: 2, Ventral view of a pedicle valve with large cicatrix,  $\times 1$ , paratype USNM 150697a; 3, 4, ventral and interior views of the preceding specimen, showing strong median elevation and few lateral lobes,  $\times 2$ ; 5, 6, side and ventral views of another pedicle valve,  $\times 1$ , holotype USNM 150697d; 7, interior of the preceding specimen, showing vallum with broad median loop in lobe and lateral lobes,  $\times 2$ ; 8, the holotype tilted posteriorly to show concave median lobe,  $\times 2$ ; 9, exterior of a complete brachial valve,  $\times 1$ , paratype USNM 150697b; 10, 11, exterior and interior of the preceding specimen,  $\times 2$ ; 12, the preceding specimen enlarged,  $\times 4$ , to show faint median ridge; 13, exterior of another brachial valve,  $\times 1$ , paratype USNM 150697c; 14, 15, interior and exterior of the preceding specimen,  $\times 2$  [Word Formation (Willis Ranch Member, lower), locality USNM 706].

16, 17, Side and exterior views of a pedicle valve,  $\times 1$ , paratype USNM 150698a; 18, interior of the preceding specimen, showing concave median inlobe,  $\times 2$  [Cherry Canyon Formation (Getaway Member), locality USNM 732].

*Poikilosakos petaloides* Watson: 19, 20, Pedical valves attached to crinoid stems,  $\times 2$ , hypotypes USNM 148045a, b [Graham Formation (Wayland Member), locality USNM 510a].

21, A fairly symmetrical pedicle valve interior,  $\times 2$ , hypotype USNM 148041 [Graham Formation (Wayland Member), locality 2150 feet north of U.S. Highway 80, 4.8 miles west of Eastland, Texas].

22, Interior of a pedicle valve with vallum and long, hollow median in-lobe,  $\times 1$ , hypotype USNM 148046; 23, interior of the preceding specimen,  $\times 2$ ; 26, 27, an elongated pedicle valve, interior view, attached to a fenestellid colony,  $\times 1$ ,  $\times 2$ , hypotype USNM 148048a [Graham Formation (Wayland Member), along the Finis to Bryson Road, 5 miles northeast of Finis, Jack County, Texas].

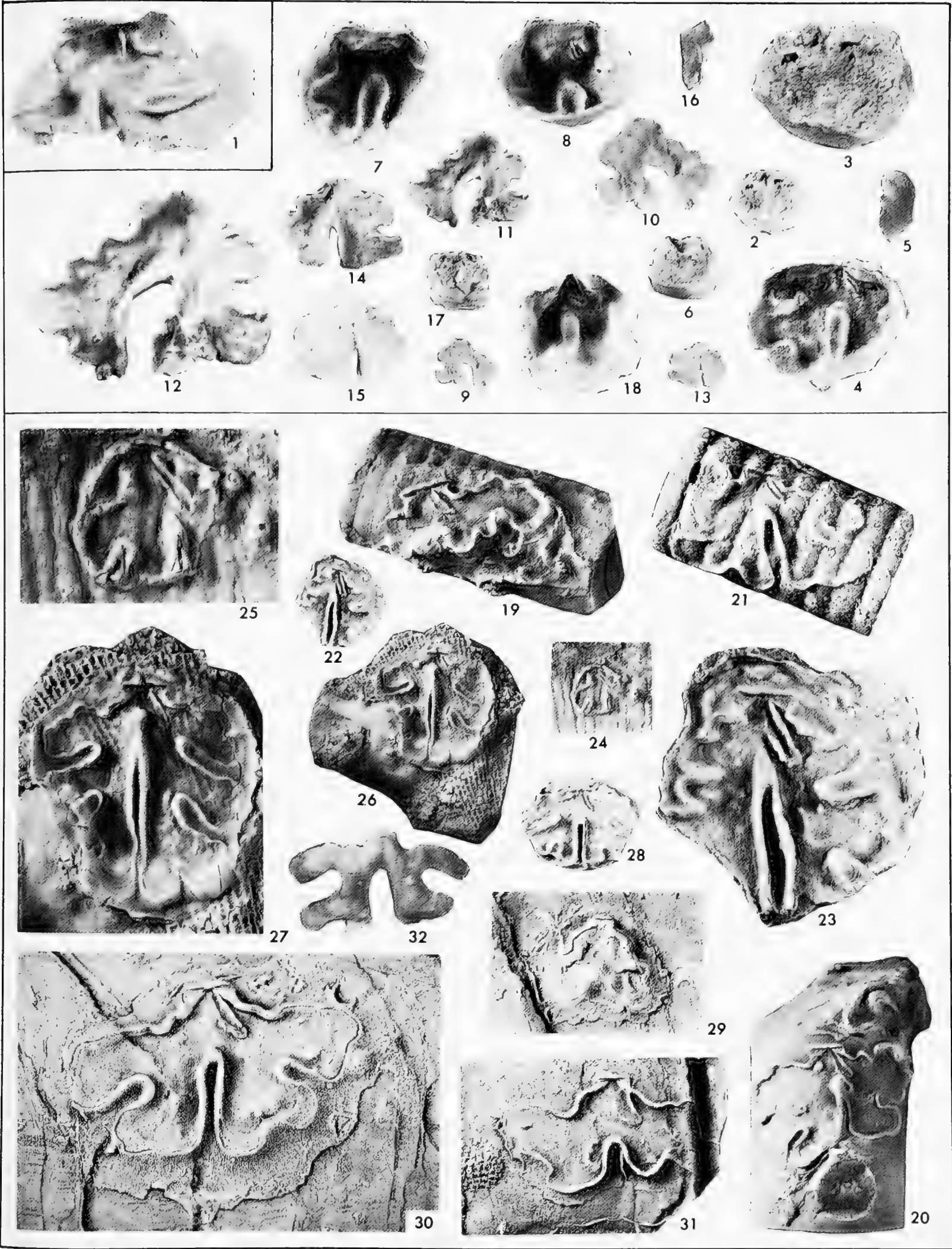
24, 25, Immature pedicle valve, showing an unusually long muscle scar,  $\times 1$ ,  $\times 3$ , hypotype USNM 150708 [Neal Ranch Formation (beds 5-8 of P. B. King), locality USNM 718e].

28, Interior of a pedicle valve with narrow, hollow median in-lobe,  $\times 1$ , hypotype USNM 148049 [Graham Formation (Wayland Member), one mile west of Graham, Texas].

29, Immature specimen with brachial valve in place,  $\times 4$ , hypotype USNM 148050a; 30, wide and fairly symmetrical pedicle valve in interior view, showing muscle scar and veneer of shell surrounding the vallum,  $\times 2$ , hypotype USNM 148050b; 31, interior view of another, smaller pedicle valve with unusually large muscle scar,  $\times 2$ , hypotype USNM 149050c [Graham Formation (Wayland Member), both sides of Bryson to Finis Road, 3.9 miles northwest of Finis, Young County, Texas].

32, Exterior of the brachial valve,  $\times 2$ , hypotype USNM 137498 [Plattsmouth Limestone, one mile south of Williamsburg, Kansas].

PLATE 127.—*Pseudoleptodus* and *Poikilosakos*.



## PLATE 128

*Pseudoleptodus*

*Pseudoleptodus guadalupensis* Stehli: 1, 2, Interior of two young pedicle valves already with conical form, incomplete vallum, and showing the oblique muscle scar,  $\times 4$ , hypotypes USNM 153651a, b; 3, 4, exterior and interior of an elongated brachial valve,  $\times 2$ , hypotype USNM 153651e; 5, exterior of another brachial valve,  $\times 2$ , hypotype USNM 153651d [Bell Canyon Formation (Rader Member), locality USNM 725f].

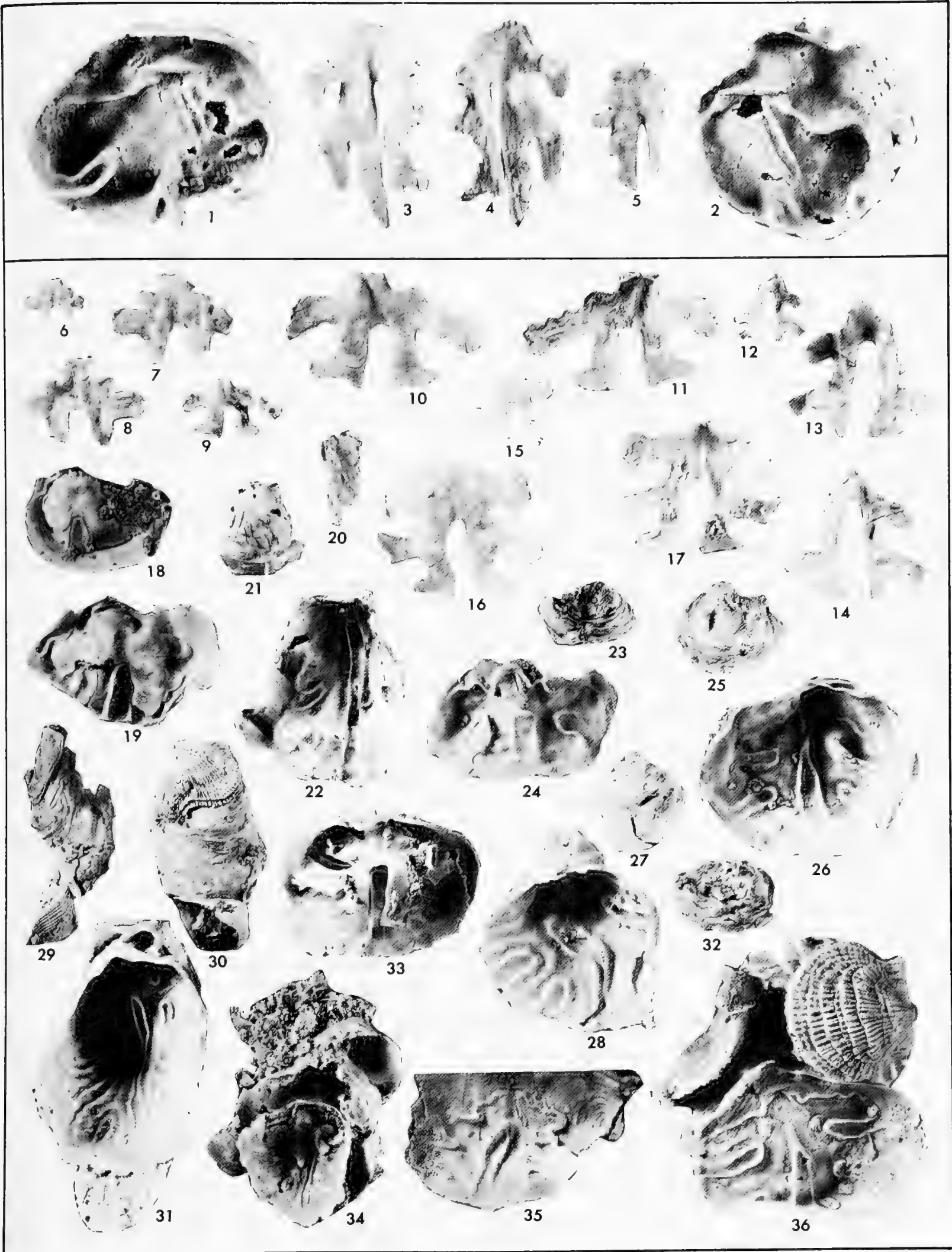
*Pseudoleptodus conicus*, new species: 6, Exterior of a small brachial valve,  $\times 1$ , paratype USNM 153652a; 7, 8, exterior and interior of the preceding specimen,  $\times 2$ ; 15, exterior of another larger brachial valve,  $\times 1$ , paratype USNM 153652b; 16, 17, exterior and interior of the preceding specimen, showing off-center cardinal process,  $\times 2$ ; 18, dorsal view of a very small individual with brachial valve in place,  $\times 4$ , paratype USNM 153652f; 19, dorsal view of a larger, but immature specimen, showing the brachial valve in place,  $\times 3$ , paratype USNM 150701h; 20, 21, side and exterior views of a fully grown valve,  $\times 1$ , paratype USNM 150701g; 22, interior of the preceding specimen,  $\times 2$ ; 23, 24, exterior view of a mature specimen,  $\times 1$ ,  $\times 2$ , paratype USNM 153652c; 25, exterior of a conical specimen,  $\times 1$ , paratype USNM 153652g; 26, interior of the preceding specimen, showing open median in-lobe,  $\times 2$ ; 27, ventral view of another conical specimen,  $\times 1$ , paratype USNM 153652d; 28, interior of the preceding individual, showing a distorted median in-lobe,  $\times 2$ ; 32, exterior of an elliptical individual,  $\times 1$ , paratype USNM 150701e; 33, dorsal view of the preceding, with brachial valve in place,  $\times 2$ ; 36, interior of a broadly conical specimen attached to a valve of *Striatifera* along with *Diplanus*, showing nearly complete vallum,  $\times 2$ , paratype USNM 153652e [Neal Ranch Formation (bed 4), locality USNM 701d].

9, Exterior of a brachial valve,  $\times 1$ , paratype USNM 150700a; 10, 11, exterior and interior of the preceding specimen, showing off-center cardinal process,  $\times 2$ ; 12, interior of another, differently shaped, brachial valve,  $\times 1$ , paratype USNM 150700b; 13, 14, exterior and interior views of the preceding specimen,  $\times 2$ ; 35, interior of a pedicle valve cemented to the brachial valve of *Striatifera*,  $\times 2$ , paratype USNM 153653 [Neal Ranch Formation (bed 4), locality USNM 271g].

29, 30, Side and ventral views of a large circumvallate pedicle valve,  $\times 1$ , holotype USNM 150702; 31, interior of the holotype, showing nearly complete vallum,  $\times 1.5$  [Neal Ranch Formation (bed 4), locality USNM 701-1].

34, Dorsal view of a cluster of attached valves, one with part of the brachial valve in place,  $\times 1$ , paratype USNM 153654a [Neal Ranch Formation (bed 4), locality USNM 727e (for additional views of specimens from this locality, see Plate 129)].

PLATE 128.—*Pseudoleptodus*.



## PLATE 129

*Pseudoleptodus*, *Coscinophora*, and *Collemataria*

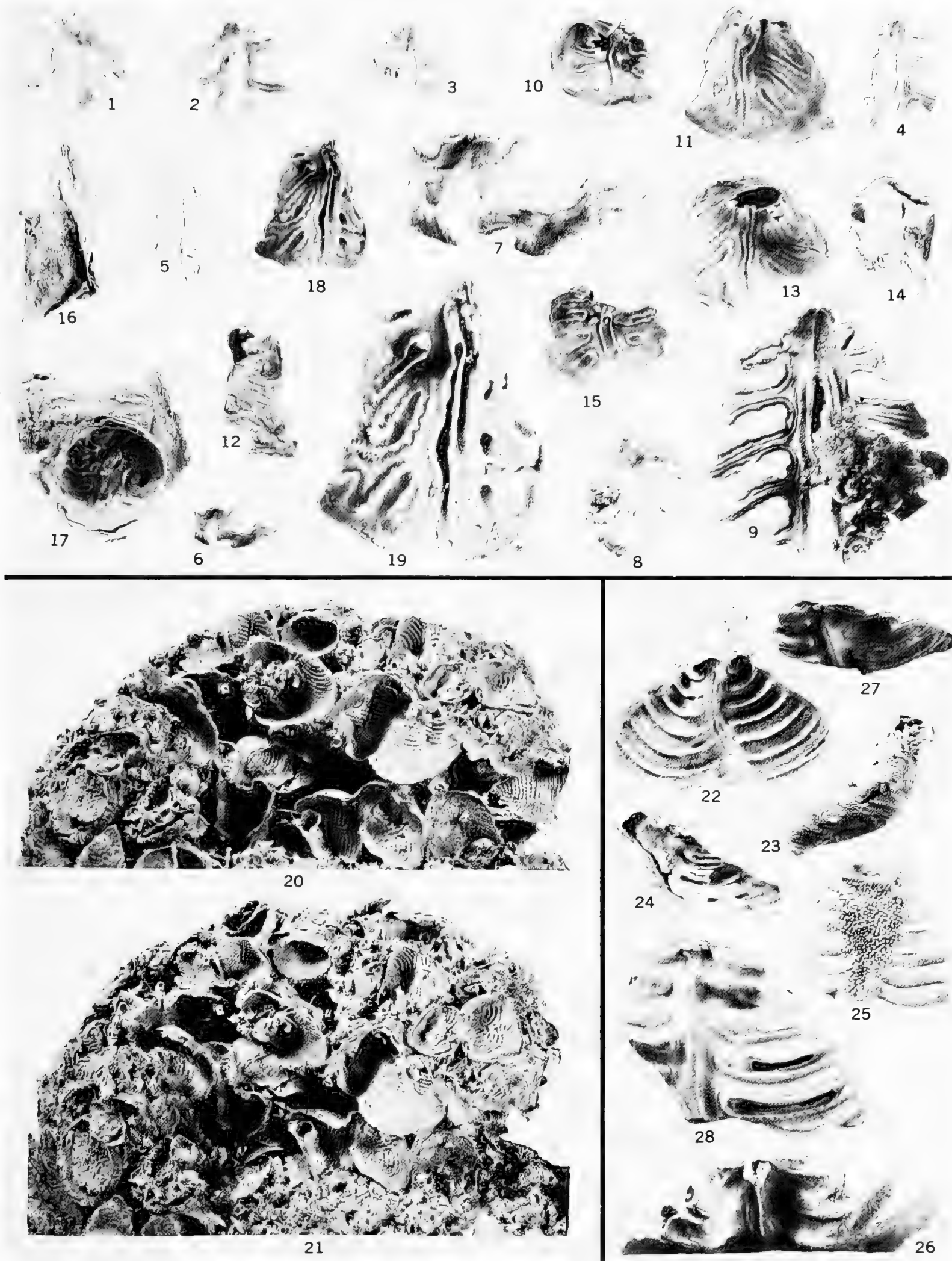
*Pseudoleptodus conicus*, new species: 1, 2, Interior and exterior of a large brachial valve,  $\times 1$ , paratype USNM 153650a; 3, exterior of another brachial valve,  $\times 1$ , paratype USNM 153650b; 4, 5, interior and exterior of a brachial valve with long median slit,  $\times 1$ , paratype USNM 153650c; 6, interior of a small brachial valve,  $\times 1$ , paratype USNM 153650d; 7, interior of the preceding specimen, showing small, off-center cardinal process,  $\times 3$ ; 8, exterior view of an unusually large and symmetrically formed brachial valve,  $\times 1$ , paratype USNM 153650e; 9, interior of the preceding specimen, showing marginal rims and low median septum  $\times 2$ ; 10, interior of the pedicle valve, showing irregularly developed lobes,  $\times 1$ , paratype USNM 153650f; 11, 12, interior and side views of another pedicle valve,  $\times 1$ , paratype USNM 153650g; 13, 14, interior and side views of a pedicle valve,  $\times 1$ , paratype USNM 153650h; 15, interior of a small, flat pedicle valve with broadly hollow median in-lobe,  $\times 1$ , paratype USNM 153650i; 16, 17, side and interior views of a nearly circular, attached pedicle valve,  $\times 1$ , paratype USNM 153650j; 18, 19, interior view of a pedicle valve with nearly complete vallum showing long hollow median in-lobe, and irregularly developed lateral lobes,  $\times 1$ ,  $\times 2$ , paratype USNM 153650k [Neal Ranch Formation (bed 4 of P. B. King), locality USNM 727e].

*Coscinophora monilifera*, new species: 20, 21, Two views of a large reefy mass, paratype USNM 153656, ca  $\times 0.20$  [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j]. For a view of the unetched mass in place, see Plate 5: figure 1 [volume I].

*Collemataria irregularis*, new species: 22, Interior of a pedicle valve, showing tube formed by posterior flap in wrapping around a crinoid stem and having solid and anguliseptate lateral ridges,  $\times 1$ , paratype USNM 153657a; 23, 24, exterior of a small, slender, and much deformed specimen,  $\times 1$ , paratype USNM 153657b; 25, exterior of a brachial valve, showing strongly granulose ornament,  $\times 1$ , paratype USNM 153657c; 26, posterior of the preceding specimen, showing the cardinal process,  $\times 2$ ; 27, posterior view of the hinge region of a brachial valve, showing the cardinal process,  $\times 1.5$ , paratype USNM 153657d; 28, interior of the preceding specimen, showing the cardinal process in more detail and the distal union of the lateral lobes,  $\times 2$  [Cathedral Mountain Formation, locality USNM 721u].



PLATE 129.—*Pseudoleptodus*, *Coscinophora*, and *Collemataria*.



## PLATE 130

*Pseudoleptodus*

*Pseudoleptodus?* species 6: 1, Attached specimen with both valves in place, seen in dorsal view,  $\times 2$ , figured specimen USNM 153641 [Cathedral Mountain Formation (Wedin Member), locality USNM 714w].

*Pseudoleptodus primitivus*, new species: 2, 3, Two views of the interior of a pedicle valve, showing the elongate, nearly tubular, oblique muscle scar, the hollow median in-lobe and the primitive vallum,  $\times 3$ , holotype USNM 150713a; 4, interior of another pedicle valve, showing a broader muscle scar but deeper median in-lobe and strong vallum, paratype USNM 150713b,  $\times 3$  [Neal Ranch Formation (top of bed 2=Gray Limestone of P. B. King) locality USNM 701].

*Pseudoleptodus?* species 5: 5, Interior of a pedicle valve attached to *Neospirifer*, showing the anterior margin lifting off the attachment,  $\times 2$ , figured specimen USNM 152625 [Cathedral Mountain Formation, locality USNM 703a<sup>1</sup>].

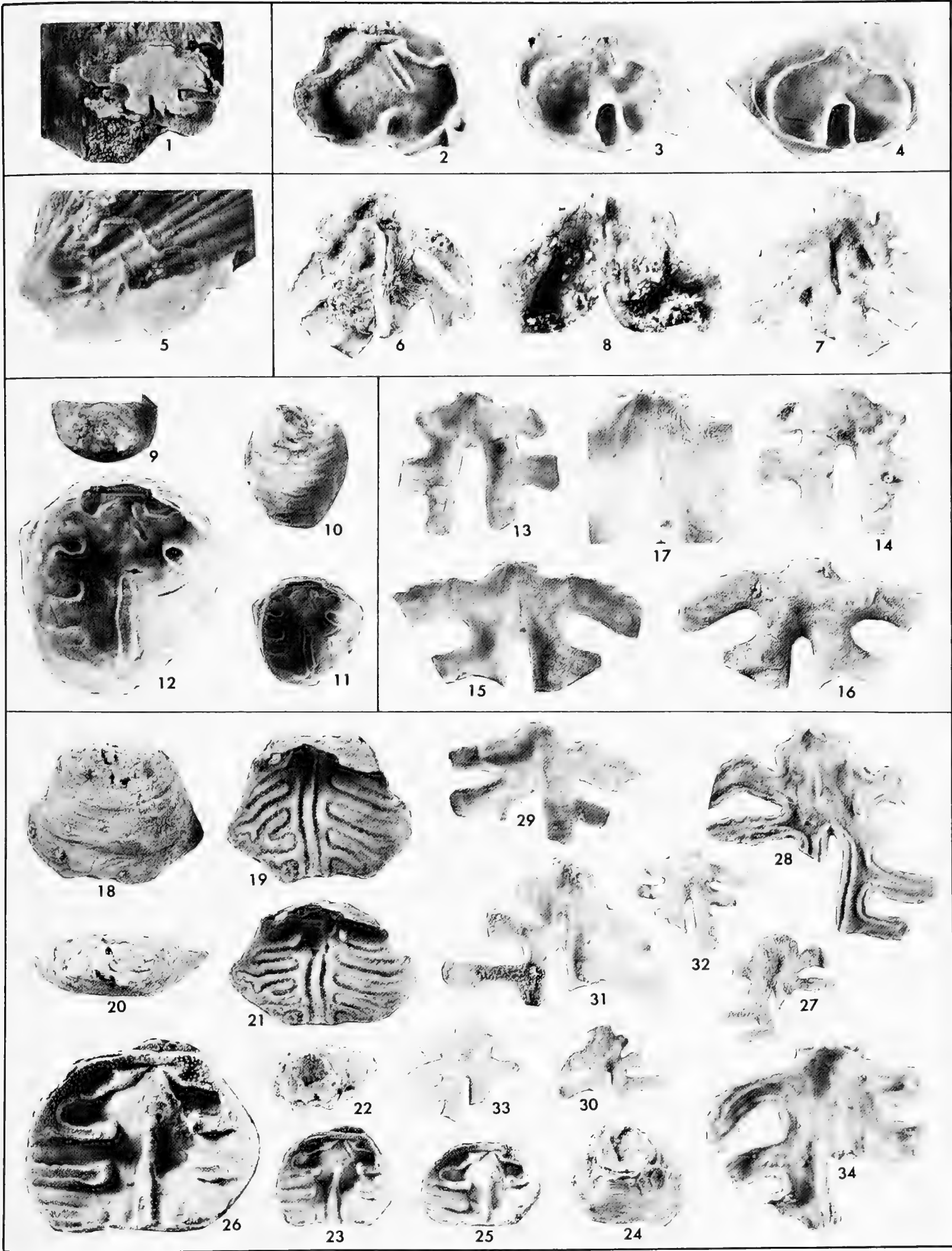
*Pseudoleptodus giganteus*, new species: 6, 7, Interior and exterior of the brachial valve,  $\times 1$ , holotype USNM 150720; 8, hinge region of the brachial valve, showing off-center cardinal process,  $\times 3$  [Road Canyon Formation, locality USNM 703].

*Pseudoleptodus cucullatus*, new species: 9–11, Posterior, ventral, and interior views of a nearly perfect circumvallate pedicle valve with small attachment cicatrix,  $\times 1$ , holotype USNM 153624a; 12, interior of the preceding specimen, showing the oblique muscle scar, latilobate lobes, and the open median in-lobe,  $\times 2$  [Cathedral Mountain Formation, locality USNM 721u].

*Pseudoleptodus?* species 3: 13, 14, Interior and exterior of a brachial valve,  $\times 2$ , figured specimen USNM 150711a; 15, 16, interior and exterior of another brachial valve,  $\times 2$ , figured specimen 150711b; 17, posteromedian portion of the preceding specimen, showing minute cardinal process and thin median septum,  $\times 4$  [Bell Canyon Formation (Hegler Member), locality USNM 731].

*Pseudoleptodus getawayensis* Stehli: 18–20, Ventral, interior, and posterior views,  $\times 1$ , holotype AMNH 27934:2, showing strongly thickened out-lobes; 21, preceding specimen tilted to show oblique muscle scar,  $\times 1$ ; 22–25, posterior, interior, exterior, posteriorly tilted views of a pedicle valve, showing attachment cicatrix,  $\times 1$ , paratype AMNH 27934:1; 26, interior of the preceding specimen, showing the oblique muscle scar and advanced augustilobate lobes,  $\times 2$ ; 27, exterior of the brachial valve,  $\times 1$ , hypotype USNM 150704b; 28, interior of the preceding,  $\times 2$ ; 29, interior of another brachial valve,  $\times 2$ , hypotype USNM 153637a; 30, exterior of a small brachial valve,  $\times 1$ , hypotype USNM 153637b; 31, interior of the preceding specimen,  $\times 2$ ; 32, 33, exterior of two brachial valves,  $\times 1$ , hypotypes USNM 153637c, d; 34, interior of a brachial valve, showing minute cardinal process,  $\times 2$ , hypotype USNM 153637e [Cherry Canyon Formation (Getaway Member), locality USNM 728=AMNH 512].

PLATE 130.—*Pseudoleptodus*.



## PLATE 131

*Pseudoleptodus*

*Pseudoleptodus guadalupensis* (Stehli): 1–3, Posterior, dorsal, and side views of long, slender unsilicified specimen,  $\times 1$ , hypotype USNM 153659a; 4–6, posterior, dorsal, and side views of a stout, unsilicified specimen,  $\times 1$ , hypotype USNM 153659b; 7–9, posterior, dorsal, and side views of a small, unsilicified specimen having a flat cicatrix,  $\times 1$ , hypotype USNM 153659c [Capitan Formation, locality USGS 7404 (blue)].

10–12, Posterior, dorsal, and side views of a stout specimen,  $\times 1$ , hypotype USNM 152622a [Capitan Formation, locality USGS, 7417 (blue)].

13, 29, Posterior and side views of a pedicle valve, showing broad cicatrix,  $\times 1$ , hypotype USNM 150717a; 30, interior of the preceding, showing hollow median loop,  $\times 2$ ; 21, 22, anterior and side views of an attached pedicle valve,  $\times 1$ , hypotype USNM 150717b; 23, interior of the preceding specimen, showing oblique muscle scar,  $\times 2$  [Bell Canyon Formation (Pinery Member), locality USNM 736].

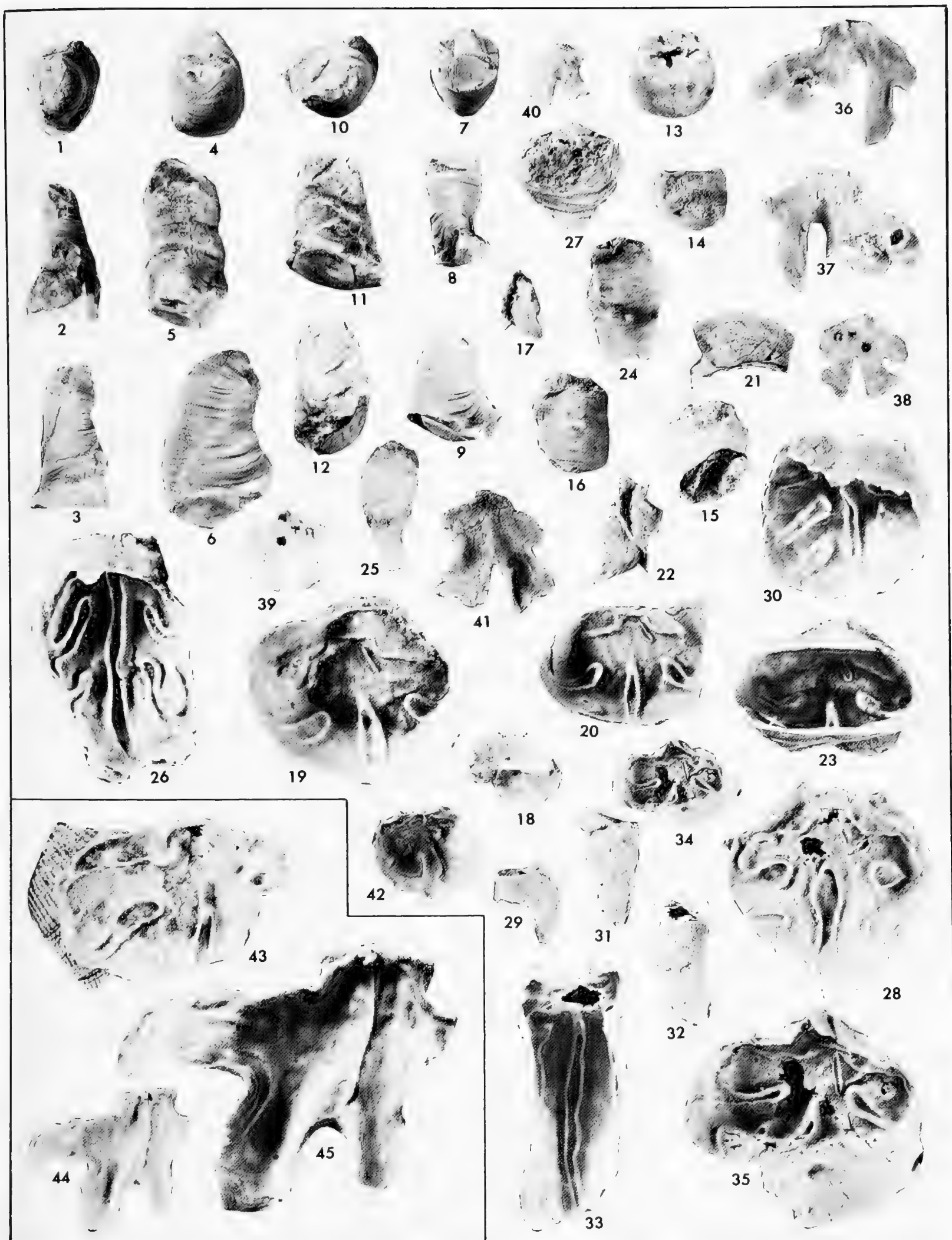
14–16, Posterior, ventral, and dorsal views of a small, deeply conical specimen,  $\times 1$ , hypotype USNM 153660a; 17, 18, side and posterior views of an attached pedicle valve,  $\times 1$ , hypotype USNM 153660b; 19, interior of the preceding specimen, showing oblique muscle scar and incomplete vallum,  $\times 3$ ; 20, interior of another youthful pedicle valve, showing hollow median in-lobes, laterally compressed in-lobes, and oblique muscle scar,  $\times 2$ , hypotype USNM 153660c; 31, 32, side and ventral views of an unusually narrow and elongated pedicle valve,  $\times 1$ , hypotype USNM 150715a; 33, interior of the preceding, showing median in-lobe,  $\times 2$ ; 36, 37, interior and exterior of a brachial valve,  $\times 2$ , hypotype USNM 153660; 38, 39, exterior and interior of a young brachial valve,  $\times 2$ , hypotype USNM 153660f; 42, interior of an immature pedicle valve,  $\times 3$ , hypotype USNM 153660g [Bell Canyon Formation (Hegler Member), locality USNM 731].

24, 25, Ventral and side views of a large pedicle valve,  $\times 1$ , hypotype USNM 153651h; 26, interior of the preceding, showing cowl and long hollow median in-lobe and nearly complete elevated vallum,  $\times 2$ ; 27, posterior of a flattish specimen with large cicatrix of attachment,  $\times 1$ , hypotype USNM 153651f; 28, interior of the preceding specimen, the flatness owing to the spat having attached to a broad and flat object,  $\times 2$ ; 34, interior of another spreading pedicle valve,  $\times 1$ , hypotype USNM 153651g; 35, interior of the preceding specimen, showing lateral compression of in-lobes,  $\times 2$ ; 40, exterior of a brachial valve,  $\times 1$ , hypotype USNM 153651c; 41, interior of the preceding,  $\times 2$  [Bell Canyon Formation (Rader Member), locality USNM 725f].

*Pseudoleptodus?* species 5: 43, Interior of the attached pedicle valve,  $\times 2$ , figured specimen USNM 152624a; 44, 45, interior of the brachial valve, showing a thin median septum and the off-center muscle scar,  $\times 2$ ,  $\times 4$ , figured specimen USNM 152624b [Cathedral Mountain Formation, locality USNM 721u].



PLATE 131.—*Pseudoleptodus*.





## PLATE 132

*Pseudoleptodus* and *Poikilosakos*

*Pseudoleptodus?* species 4: 1, 2. Interior and exterior views of a brachial valve,  $\times 2$ , figured specimen 150712a [Cathedral Mountain Formation, locality USNM 708u].

*Pseudoleptodus lepidus*, new species: 3, 4, Ventral and side views of a pedicle valve with latilobate outlobes, compressed in-lobes, and hollow median in-lobe, attached to a large *Composita*,  $\times 1$ , holotype USNM 152623f; 5, interior of the preceding specimen, showing the oblique muscle scar and the narrow, hollow median in-lobe,  $\times 2$ ; 6, exterior of a large, irregular brachial valve,  $\times 1$ , paratype USNM 152623a; 7, 8, interior and exterior of the preceding specimen,  $\times 2$ ; 9, exterior of a small brachial valve,  $\times 1$ , paratype USNM 152623b; 10, 11, interior and exterior of the preceding specimen, showing granular ornament,  $\times 3$ ; 12, exterior of a small brachial valve,  $\times 1$ , paratype USNM 152623c; 13, 14, exterior and interior of the preceding specimen,  $\times 2$  [Word Formation (Appel Ranch Member), locality USNM 719z].

*Pseudoleptodus granulosus*, new species: 15, Exterior of a round pedicle valve,  $\times 1$ , paratype USNM 150714a; 16, interior view of the preceding specimen, showing hollow median in-lobe and granules on the lateral and median in-lobes,  $\times 2$ ; 17, exterior of another pedicle valve, showing *Isogramma* ornament from shell to which it had been attached,  $\times 1$ , holotype USNM 150714b; 18, interior of the holotype, showing complete vallum, in-loop granules, and oblique muscle scar,  $\times 2$ ; 19, exterior of a brachial valve,  $\times 1$ , paratype USNM 150714c; 20, 21, exterior and interior of the preceding brachial valve, showing cardinal process and granular exterior,  $\times 2$  [Bone Spring Formation, locality USNM 728f].

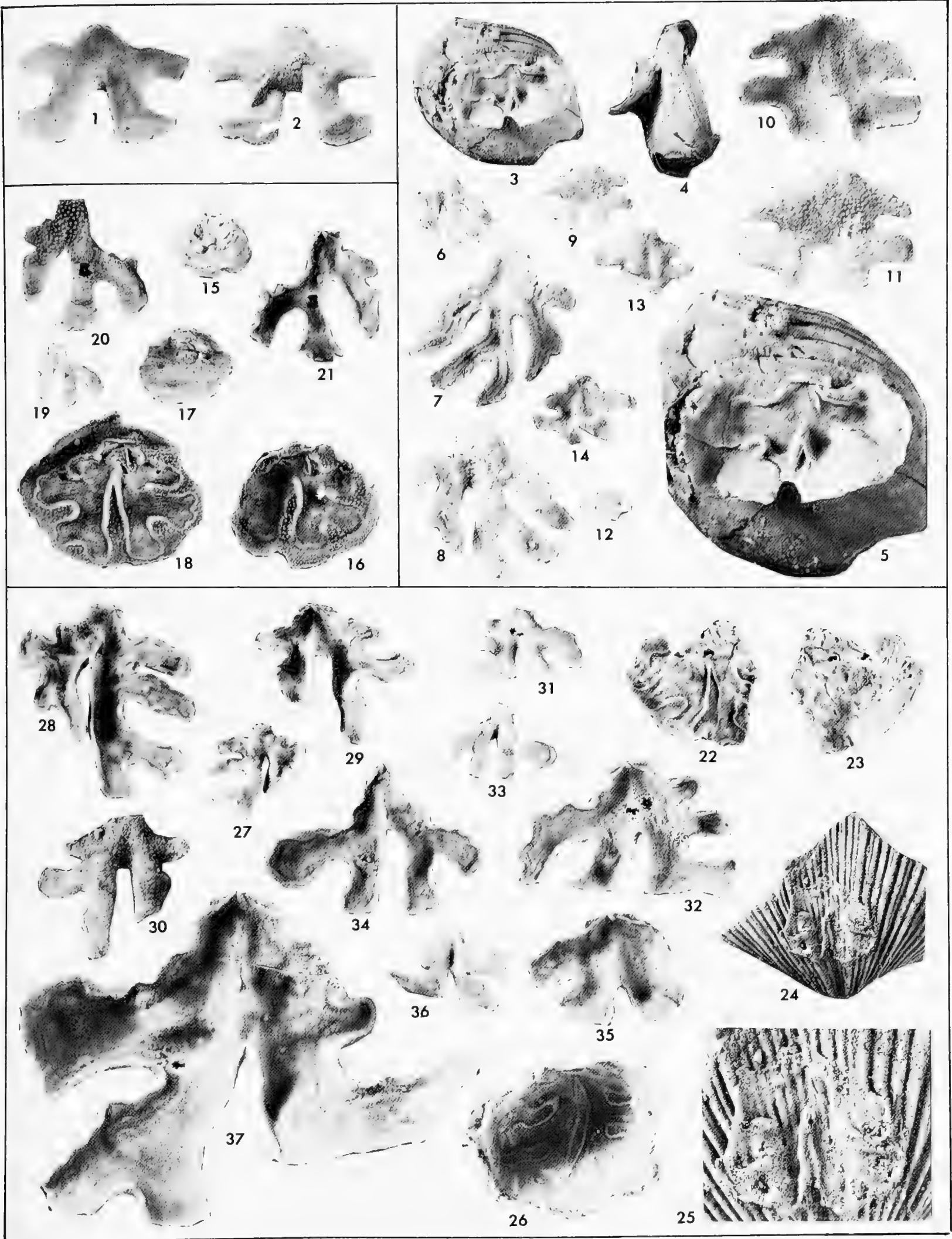
*Poikilosakos informis*, new species: 22, 23, Interior and exterior of a large, flaky pedicle valve with strong vallum,  $\times 1$ , holotype USNM 152619a; 24, 25, dorsal view of a young pedicle valve attached to *Neospirifer*,  $\times 1$ ,  $\times 2$ , paratype USNM 152619b; 31, exterior of a brachial valve,  $\times 1$ , paratype USNM 152619c; 32, interior of the preceding specimen,  $\times 2$  [Bone Spring Formation, locality AMNH 629].

26, Pedicle valve attached inside the curve of a productid pedicle valve, showing incomplete vallum,  $\times 2$ , paratype USNM 152620a; 29, 30, interior and exterior views of a brachial valve,  $\times 2$ , paratype USNM 152620b [Skinner Ranch Formation (base), locality USNM 705a].

27, Exterior of a large, unsymmetrical brachial valve,  $\times 1$ , paratype USNM 150694e; 28, interior of the preceding specimen,  $\times 2$ ; 33, exterior of another brachial valve with one expanded lobe,  $\times 1$ , paratype USNM 150694b; 34, interior of the preceding specimen, showing the off-center cardinal process,  $\times 2$ ; 36, exterior view of another irregular brachial valve,  $\times 1$ , paratype USNM 150694a; 37, interior of the preceding specimen, showing cardinal process,  $\times 3$  [Bone Spring Formation, locality USNM 728f].

35, Interior of a small brachial valve, showing the cardinal process,  $\times 2$ , paratype USNM 150693 [Bone Spring Formation, locality AMNH 631].

PLATE 132.—*Pseudoleptodus* and *Poikilosakos*.



## PLATE 133

*Collemataria*, *Choanodus*, and *Pseudoleptodus*

*Collemataria marshalli* (Stehli): 1–3, Ventral, side, and interior views of a medium-sized pedicle valve attached to a crinoid stem and showing angustilobate septa,  $\times 1$ , hypotype USNM 150767e [Bone Spring Formation (base), locality USNM 728e].

*Collemataria irregularis*, new species: 4, Interior of an incomplete pedicle valve attached to entire inner surface of *Institella*, giving the appearance of a leptodid with spines,  $\times 1$ , paratype USNM 153643; 5, 6, exterior and interior of the preceding specimen,  $\times 2$ ,  $\times 1$  [Cathedral Mountain Formation, locality USNM 721u].

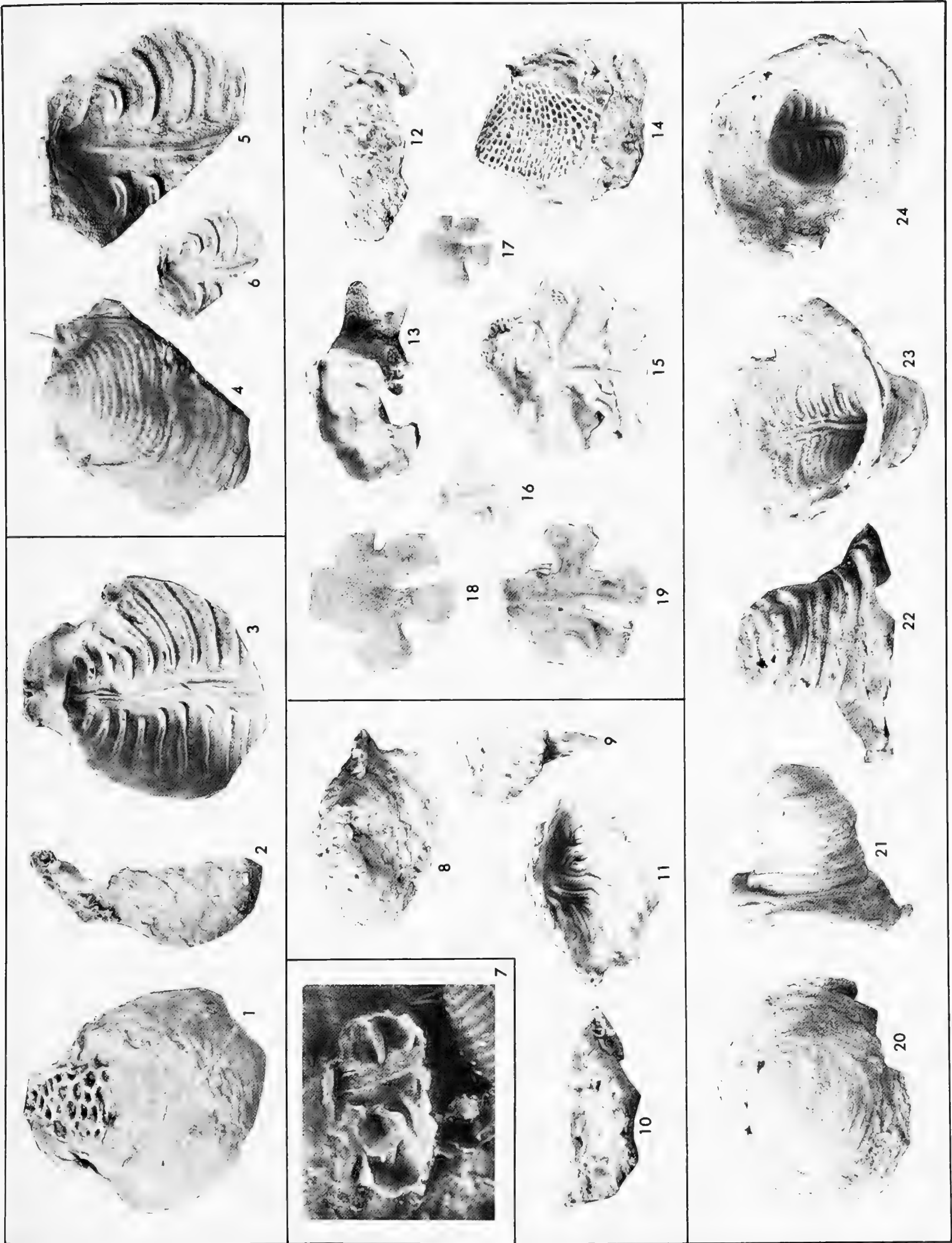
*Collemataria gregaria*, new species: 7, Interior of a pedicle valve attached to *Rugatia* and showing angustilobate to solidiseptate septa,  $\times 2$ , figured paratype USNM 153644 [Cathedral Mountain Formation, locality USNM 702].

*Choanodus irregularis*, new species: 8–11, Ventral, side, posterior, and interior views of a strongly conical pedicle valve, with crowded lateral lobes,  $\times 1$ , paratype USNM 153645 [Cathedral Mountain Formation, locality USNM 726u].

*Pseudoleptodus grandis*, new species: 12, 13, Exterior and interior of a complete specimen,  $\times 1$ , paratype USNM 153646a; 14, 15, exterior and interior of a large pedicle valve attached to a fenestellid frond and showing angustilobate lateral septa,  $\times 1$ , paratype USNM 153646b; 16, 17, interior and exterior of a small brachial valve,  $\times 1$ , paratype USNM 153646c; 18, 19, exterior and interior of the preceding specimen, showing finely granular surface and small cardinal process,  $\times 2$  [Word Formation, locality USNM 732c].

*Choanodus perfectus*, new species: 20–24, Ventral, side, posterior, dorsal, and anterior views, showing conical form of cup and numerous angustilobate lobes,  $\times 1$ , paratype USNM 154647 [Cathedral Mountain Formation, locality USNM 726u].

PLATE 133.—*Collemataria*, *Choanodus*, and *Pseudoleptodus*.



## PLATE 134

*Coscinophora* and *Choanodus*

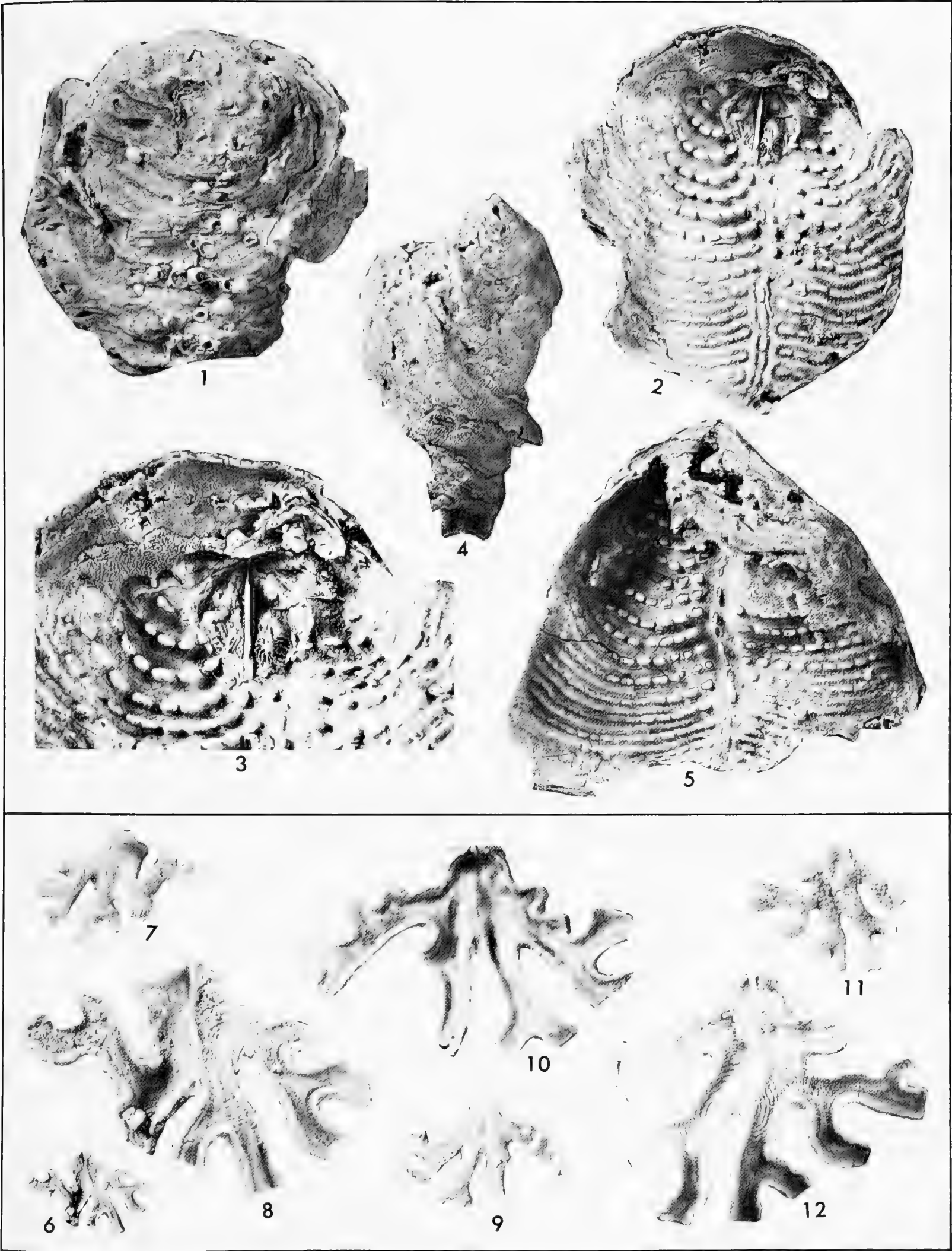
*Coscinophora hortonii* (R. E. King): 1, 2, Ventral and dorsal views of a pedicle valve preserving the muscle scars and median myophragm,  $\times 1$ , hypotype USNM 150860a; 3, posterior of the preceding specimen enlarged to show the median myophragm and dendritic adductor scars,  $\times 2$ ; 4, 5, side and dorsal (interior) views of a pedicle valve with large cowl,  $\times 1$ , hypotype USNM 150860b [Cathedral Mountain Formation (Wedin Member), locality USNM 714w].

*Choanodus irregularis*, new species: 6, Interior of the brachial valve,  $\times 1.5$ , paratype USNM 150826d; 7, exterior of the preceding specimen, showing granular surface,  $\times 2$ ; 8, interior of the preceding, showing marginal elevated ridges on the lobes,  $\times 3$  [Cathedral Mountain Formation, locality USNM 702].

9, Exterior of another granulose brachial valve,  $\times 2$ , paratype USNM 150828a; 10, interior of the preceding specimen, showing off-center cardinal process,  $\times 3$ ; 11, exterior of a strongly granulose brachial valve,  $\times 2$ , paratype USNM 150828d; 12, interior of the preceding specimen, showing off-center cardinal process,  $\times 3$  [Cathedral Mountain Formation, locality USNM 702a].



PLATE 134.—*Coscinophora* and *Choanodus*.



## PLATE 135

*Choanodus*

*Choanodus irregularis*, new species: 1-4, Posterior, interior, ventral, and side views of a pedicle valve with narrow thickened lobes,  $\times 1$ , paratype USNM 153606 [Cathedral Mountain Formation, locality USNM 721u].

5-7, Interior, side, and ventral views of a pedicle valve with thick solidiseptate lobes,  $\times 1$ , paratype USNM 150827a; 8-10, posterior, interior, and ventral views of a small individual,  $\times 1$ , paratype USNM 150827c; 27, 28, exterior and interior of another immature pedicle valve,  $\times 1$ , paratype USNM 153604; 29, interior of a fully grown pedicle valve, showing long median ridge and irregular lobation, and the lobate posterior lobe,  $\times 2$ , paratype USNM 150827g; 30-32, posterior, interior, and exterior views of a small individual, showing well-developed cowl,  $\times 2$ , paratype USNM 150827f; 34, fully grown pedicle valve attached to a large lyttoniid,  $\times 1$ , paratype USNM 150827e; 35, 36, interior,  $\times 1.5$ , and exterior,  $\times 2$ , views of a brachial valve, paratype USNM 150826e; 37, dorsal view of a specimen preserving the brachial valve in place,  $\times 2$ , paratype USNM 150826a [Cathedral Mountain Formation, locality USNM 702].

11-14, Side, exterior, posterior,  $\times 1$ , and interior,  $\times 1.5$ , views of a large pedicle valve with solidiseptate lobes, paratype USNM 150835f; 19-22, exterior, side, interior, and posterior views of a young pedicle valve,  $\times 1$ , paratype USNM 150835e; 33, dorsal view of a fully grown adult with part of brachial valve in place,  $\times 2$ , paratype USNM 150835b. [Cathedral Mountain Formation, locality USNM 703b].

15-18, Interior, exterior, side, and posterior views of an adult with part of the brachial valve in place,  $\times 1$ , paratype USNM 153605 [Cathedral Mountain Formation, locality USNM 703a].

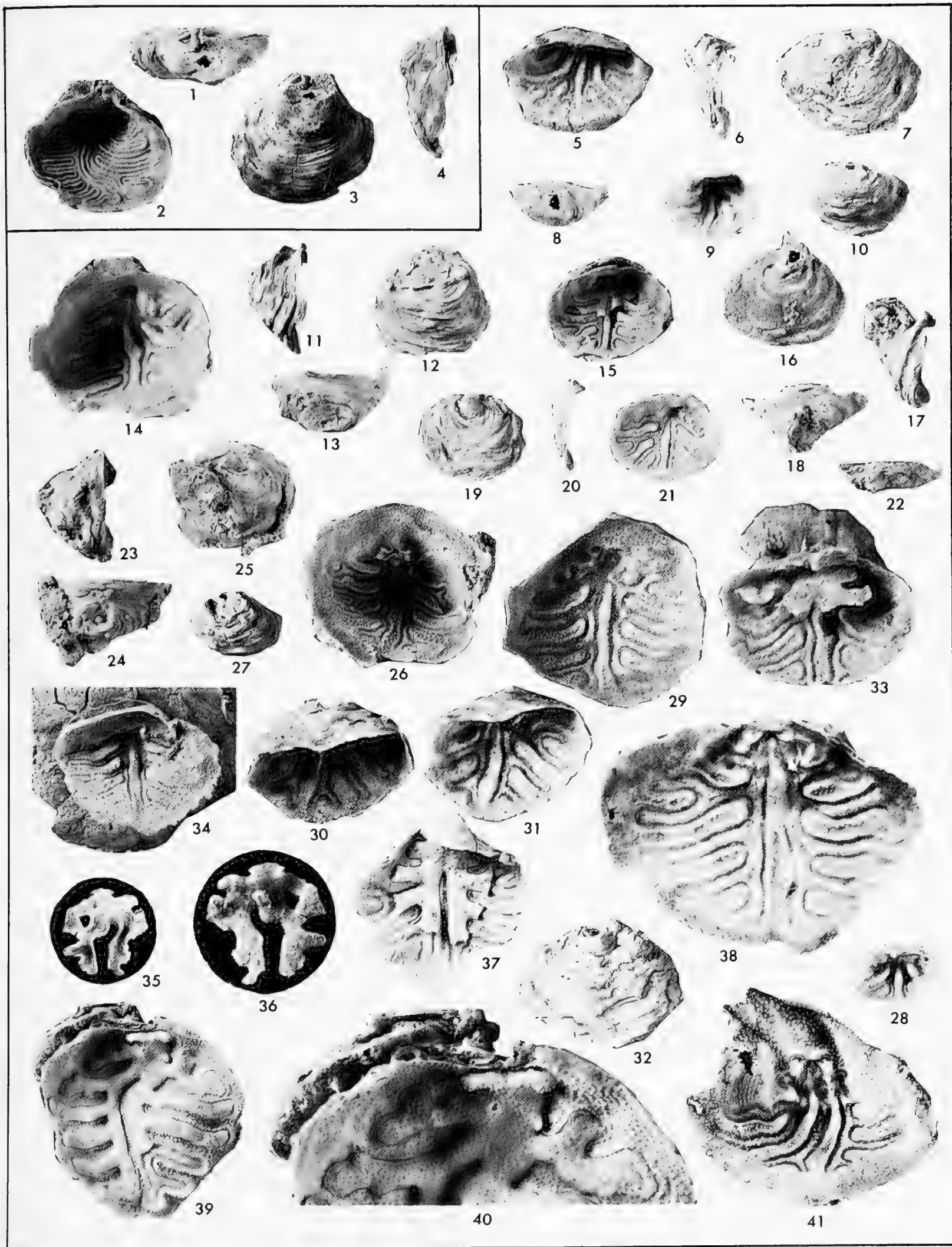
23-25, Side, posterior, and ventral views of a specimen with well-developed cowl,  $\times 1$ , paratype USNM 150840; 26, interior of preceding specimen,  $\times 2$  [Cathedral Mountain Formation, locality USNM 714w].

38, Interior view of a complete adult, showing granulose in-lobes,  $\times 3$ , paratype USNM 150842 [Bone Spring Formation, locality AMNH 658].

39, Dorsal view of a complete specimen but with damaged cowl,  $\times 2$ , holotype USNM 150838; 40, posterior of the preceding specimen, showing articulation and lobation,  $\times 4$  [Cathedral Mountain Formation, locality USNM 712o].

41, Pedicle valve tilted to show hinge region,  $\times 2$ , paratype USNM 150830 [Cathedral Mountain Formation, locality USNM 7021ow].

PLATE 135.—*Choanodus*.



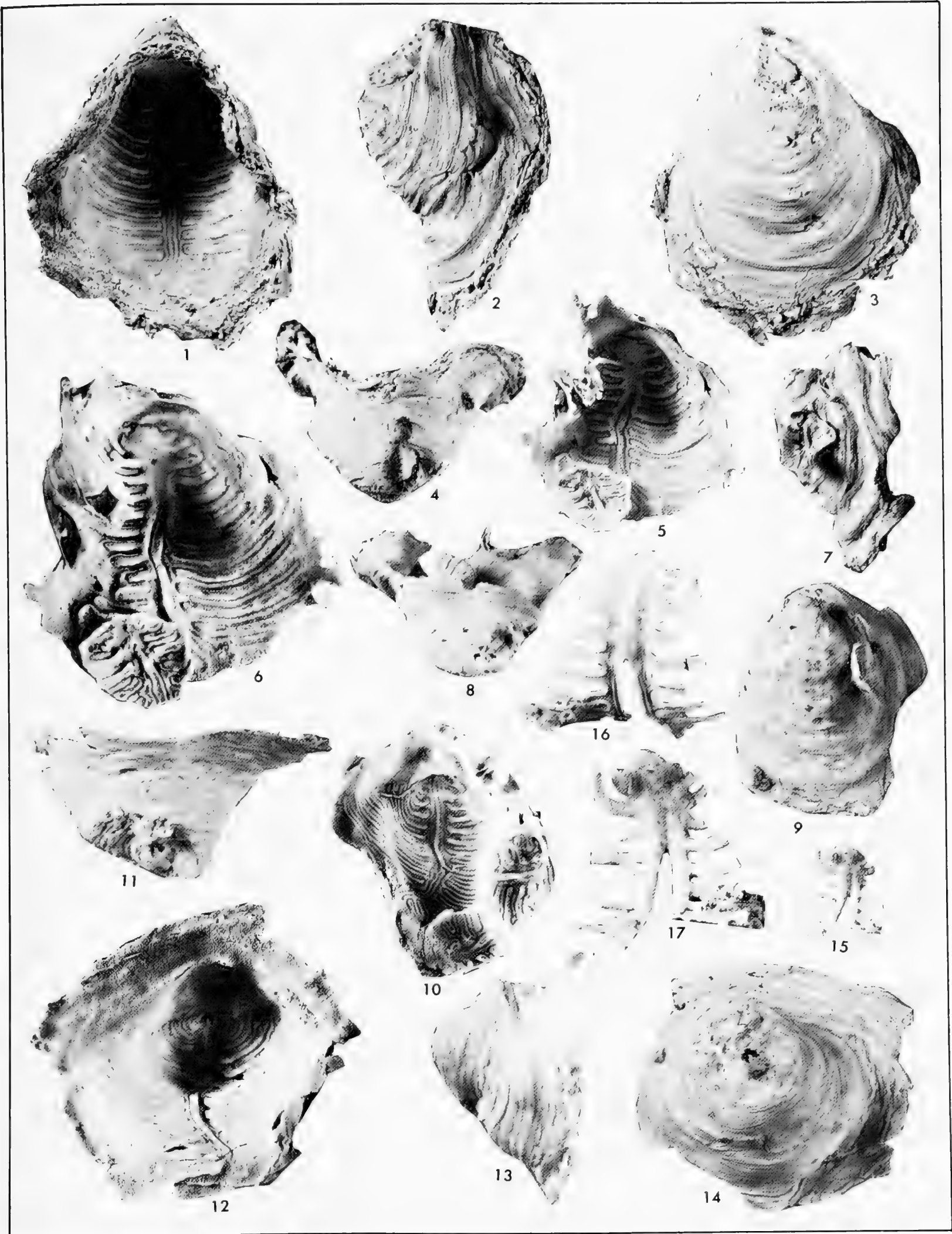
## PLATE 136

*Choanodus*

*Choanodus perfectus*, new species: 1-4, Interior, side, ventral, and posterior views of a large pedicle valve, showing regular, closely crowded lobes,  $\times 1$ , paratype USNM 150846a; 5, interior of another pedicle valve with part of brachial valve in place,  $\times 1$ , holotype USNM 150846b; 6, same as preceding,  $\times 1.5$ ; 7-10, side, posterior, ventral, and interior views of another pedicle valve with young individuals attached,  $\times 1$ , paratype USNM 150846d; 11-14, posterior, interior, side, and ventral views of another flaring pedicle valve,  $\times 1$ , paratype USNM 150846e; 15, exterior of a small brachial valve,  $\times 1$ , paratype USNM 150845a; 16, 17, interior and exterior views of the preceding specimen, showing deep axial cleft,  $\times 2$  [Cathedral Mountain Formation, locality USNM 702un].



PLATE 136.—*Choanodus*.





## PLATE 137

*Choanodus* and *Loxophragmus*

*Choanodus perfectus*, new species: 1-3, Interior, side, and posterior views of a small adult pedicle valve,  $\times 1$ , paratype USNM 153607a; 4, 5, interior and posterior views of another small pedicle valve with attached sponge,  $\times 1$ , paratype USNM 153607b [Cathedral Mountain Formation, locality USNM 721u].

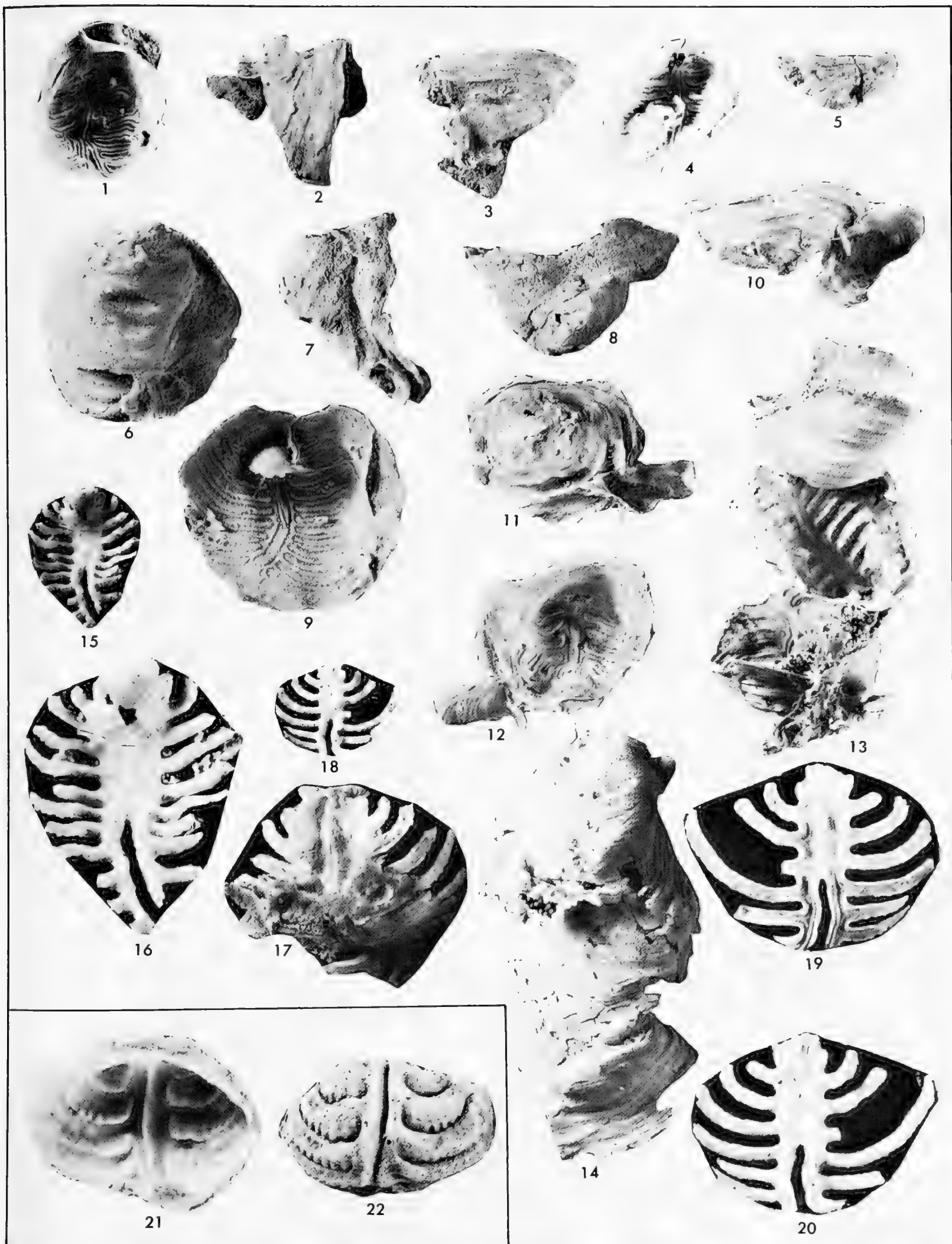
6-9, Ventral, side, posterior, and interior views of a large pedicle valve, showing augustilobate septa and attached *Xenosteges*,  $\times 1$ , paratype USNM 153608 [Cathedral Mountain Formation, locality USNM 702b].

10-12, Posterior, ventral, and interior views of another pedicle valve, with augustilobate ridges,  $\times 1$ , paratype USNM 153609 [Cathedral Mountain Formation (Wedin Member), locality USNM 727p].

13, 14, Interior and exterior views of a cluster of attached valves,  $\times 1$ , paratype USNM 153610; 15, 16, exterior of a large brachial valve,  $\times 1$ ,  $\times 2$ , paratype USNM 150845c; 17, interior of the preceding specimen,  $\times 2$ ; 18, exterior of another brachial valve,  $\times 1$ , paratype USNM 150845b; 19, 20, interior and exterior of the preceding specimen,  $\times 2$  [Cathedral Mountain Formation, locality USNM 702un].

*Loxophragmus ellipticus*, new species: 21, Interior of a pedicle valve, showing the oblique augulisepta with their striated or fluted margins,  $\times 2$ , paratype USNM 153611; 22, latex impression of the interior of the preceding specimen, showing the form of the lobes fluting mold of the interior [Cathedral Mountain Formation, locality USNM 701b].

PLATE 137.—*Choanodus* and *Loxophragmus*.



## PLATE 138

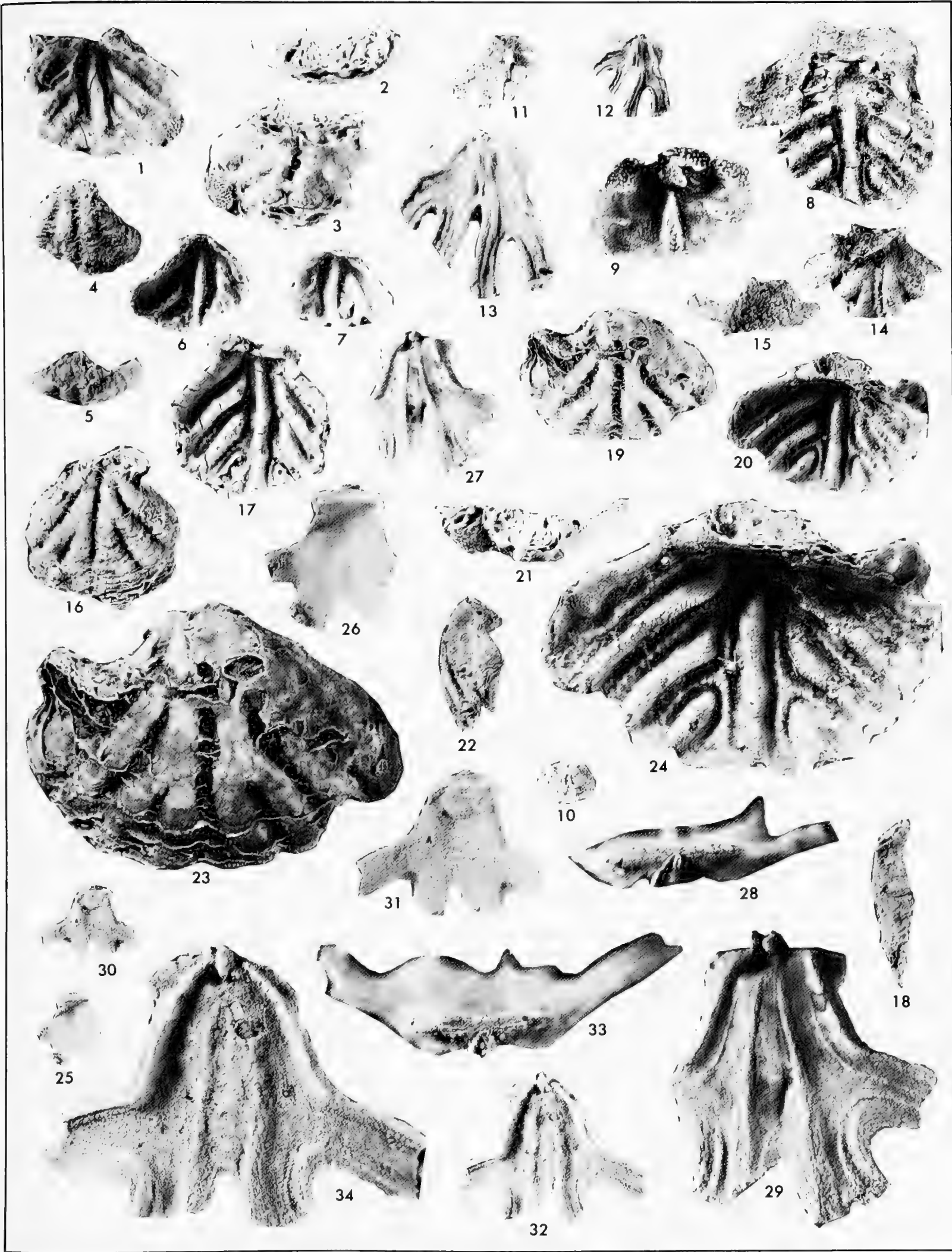
*Sceletonia*

*Sceletonia crassa*, new species: 1-3, Interior, posterior, and exterior (ventral) views of a small pedicle valve  $\times 1$ , paratype USNM 153587a; 8, interior of another, larger pedicle valve, with thick solidiseptate in-lobes,  $\times 1$ , paratype USNM 153587b [Skinner Ranch Formation (Dugout Mountain Member, part = Second Limestone of the Leonard of P. B. King), locality USNM 732e].

4-6, Ventral (exterior), posterior, and interior view of a small individual,  $\times 1$ , paratype USNM 151328a; 7, interior of another immature specimen,  $\times 1$ , paratype USNM 151328f; 9, 10, interior,  $\times 3$ , and exterior,  $\times 1$ , of a very young specimen, showing eccentric diductor muscle scar, paratype USNM 151328e; 14, 15, exterior and posterior of a small pedicle valve,  $\times 1$ , paratype USNM 151328g; 16-18, exterior (ventral), interior, and side views of a larger pedicle valve, showing thick in-lobes,  $\times 1$ , paratype USNM 151328d; 19-22, ventral (exterior), interior, posterior, and side views of a large pedicle valve, showing thick in-lobes defining deep channels,  $\times 1$ , holotype USNM 151328h; 23, 24, exterior and interior of the holotype,  $\times 2$ ; 25, exterior of an imperfect brachial valve,  $\times 1$ , paratype USNM 151328i; 26, 27, exterior and interior of the preceding specimen, showing eccentric cardinal process,  $\times 2$ ; 28, 29, posterior and interior of the preceding specimen, showing the cardinal process, one prong of which is partly broken,  $\times 4$ ; 30, exterior of another, more complete brachial valve,  $\times 1$ , paratype USNM 151328j; 31, 32, exterior and interior of the same specimen,  $\times 2$ ; 33, 34, posterior and interior of the preceding specimen showing the cardinal process and internal ridges,  $\times 4$  [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 722-1].

11, 12, Exterior and interior of a brachial valve,  $\times 1$ , paratype USNM 152626; 13, interior of the preceding specimen enlarged,  $\times 2$  [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 727a].

PLATE 138.—*Sceletonia*.



## PLATE 139

*Pseudoleptodus*, *Sceletonia*, and *Collemataria*

*Pseudoleptodus?* species 2: 1, 2, Exterior and interior of an imperfect brachial valve,  $\times 2$ , figured specimen USNM 150710 [Bone Spring Formation, locality AMNH 591].

*Sceletonia crassa*, new species: 3, Fragment of the interior of a pedicle valve,  $\times 1$ , figured specimen USNM 153588a; 4, 5, exterior and interior of an incomplete brachial valve,  $\times 1$ , figured specimen USNM 153588b; 6, interior of the preceding specimen, showing cardinal process,  $\times 2$  [Bone Spring Formation, locality USNM 725c].

*Sceletonia crassa*, new species: 7, 8, Exterior and interior of a fragment of a pedicle valve,  $\times 1$ , figured specimen USNM 153589a; 9, 10, exterior and interior of a fragmentary brachial valve,  $\times 1$ , figured specimen USNM 153589b [Bone Spring Formation, locality AMNH 591].

*Collemataria elongata*, new species: 11, Dorsal view of a small, distorted individual, showing very irregular development of the lobes of the brachial valve,  $\times 1$ , paratype USNM 153638a [Word Formation (Willis Ranch Member), locality USNM 706e].

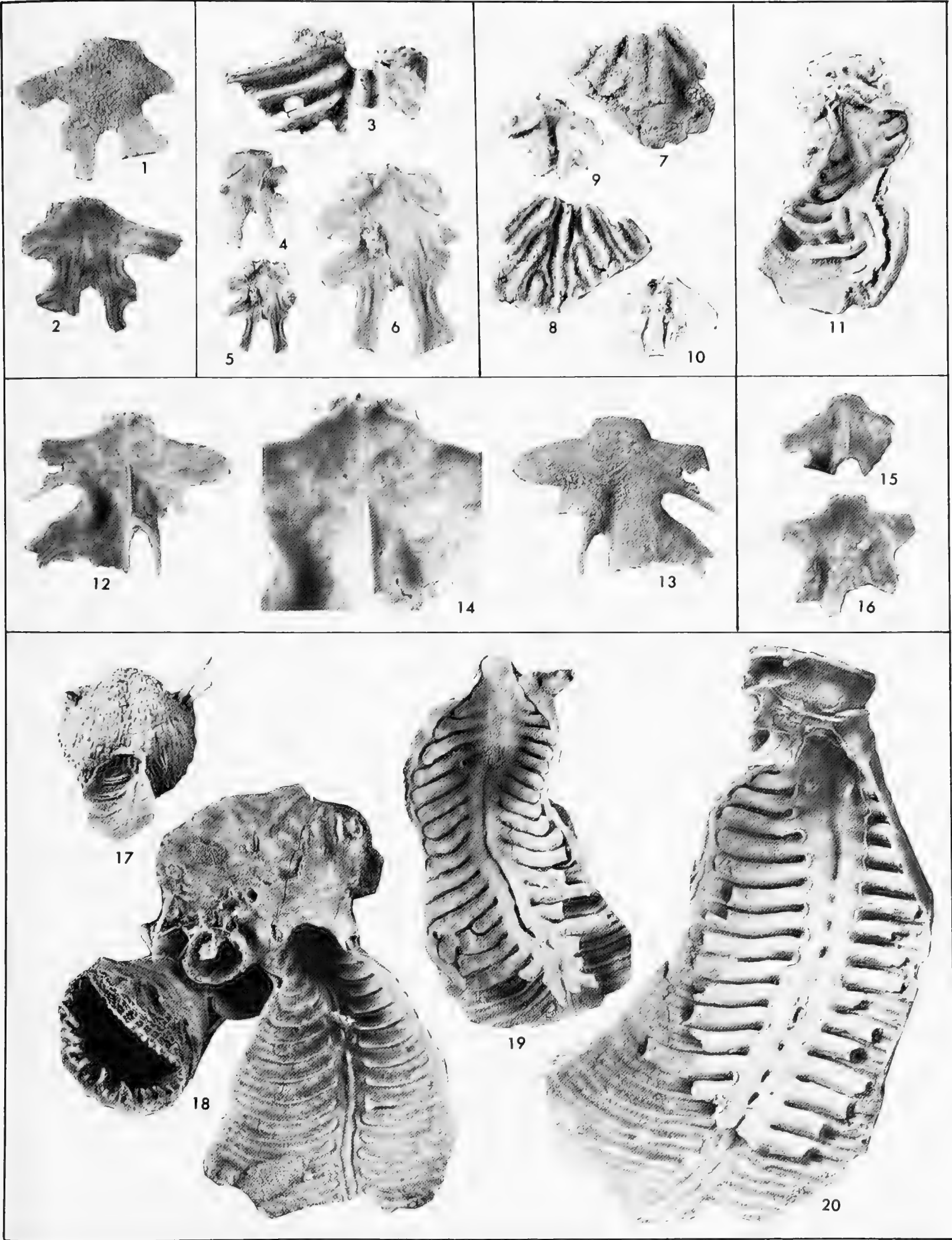
*Pseudoleptodus?* species 1: 12, 13, Interior and exterior of an imperfect brachial valve,  $\times 2$ , figured specimen USNM 153639; 14, median portion of the brachial valve interior of the preceding specimen, showing median septum,  $\times 4$  [Bone Spring Formation, locality AMNH 46].

*Pseudoleptodus?* species 7: 15, 16, Interior view of two imperfect, septate brachial valves,  $\times 2$ , figured specimens USNM 153640a, b [Road Canyon Formation, locality USNM 724c].

*Collemataria elongata*, new species: 17, Dorsal view of a small pedicle valve attached to the pedicle valve of *Rhamnaria*,  $\times 1$ , paratype USNM 153638b; 18, dorsal view of a large pedicle valve attached to *Echinosteges* and showing the dorsal flap of attachment,  $\times 1$ , paratype USNM 153638c; 19, specimen in dorsal view, showing the brachial valve in place, an open slit in the anterior part of the axis, and fairly symmetrical lobe development,  $\times 1$ , paratype USNM 153638d; 20, complete specimen, showing closing of pores in the axis,  $\times 1.5$ , holotype USNM 150821s [Word Formation (Willis Ranch Member), locality USNM 706e].



PLATE 139.—*Pseudoleptodus*, *Sceletonia*, and *Collemataria*.

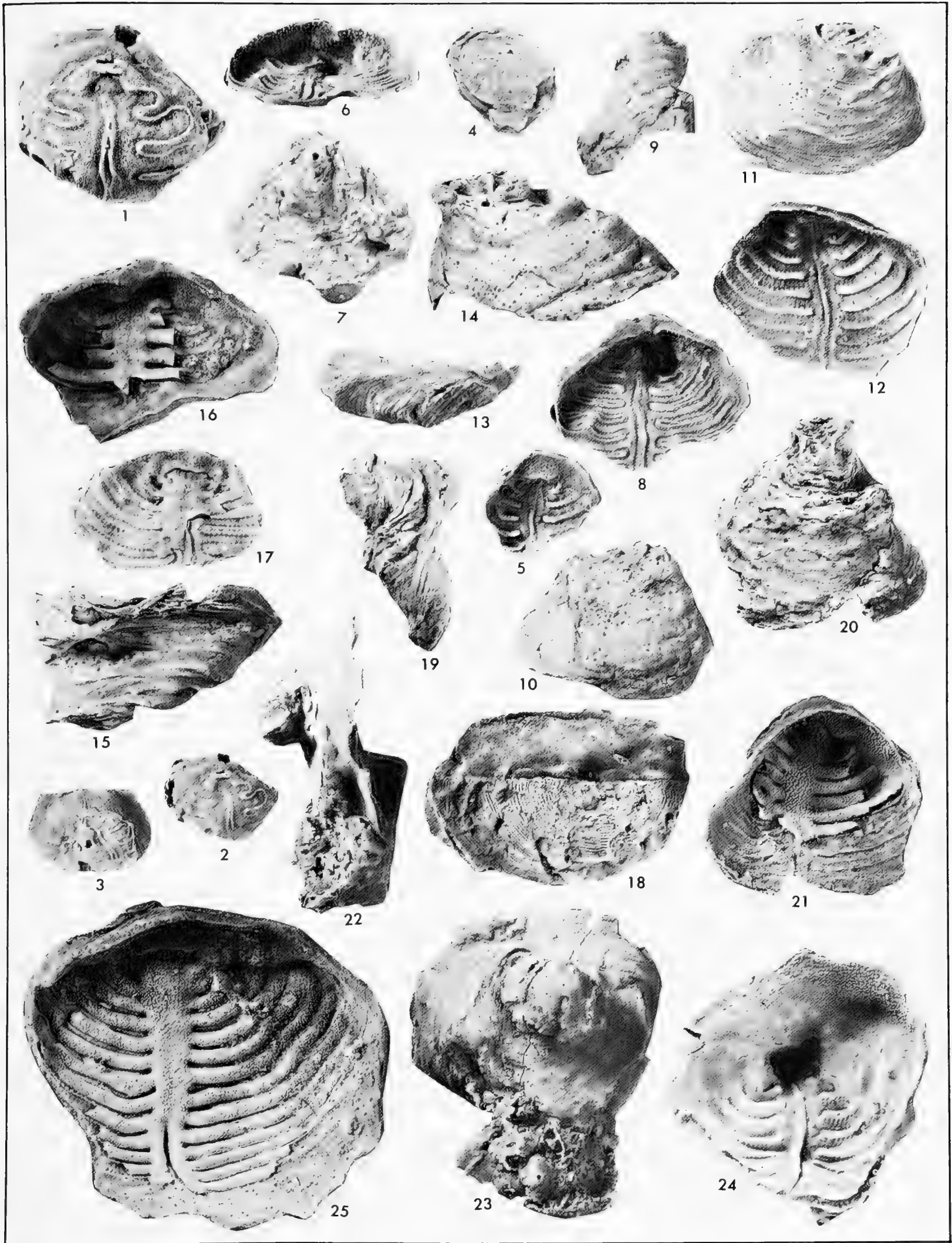


## PLATE 140

*Eolyttonia*

*Eolyttonia diabloensis* (Stehli): 1, 2, Young specimen starting life attached to a *Rhynchopora* shell and showing nearly complete vallum (note absence of oblique muscle scar),  $\times 2$ ,  $\times 1$ , hypotype USNM 153586a; 3, another young one growing on a small *Derbyia*,  $\times 1$ , hypotype USNM 153586b; 4, 5, exterior and interior of a youthful pedicle valve that started life on the shell of *Isogramma*,  $\times 1$ , hypotype USNM 153586c; 6-8, interior tilted posteriorly, exterior and interior of a pedicle valve,  $\times 1$ , hypotype USNM 153586d; 9, 10, side and ventral views of a small, conical specimen,  $\times 1$ , hypotype USNM 153586e; 11-13, ventral, interior, and posterior views of another pedicle valve,  $\times 1$ , hypotype USNM 153586f; 14, 15, side and posterior views of a fairly large conical specimen with long cowl,  $\times 1$ , hypotype USNM 153586h; 16, interior of a pedicle valve with part of the brachial valve in place and having a short, broad cowl,  $\times 1$ , hypotype USNM 153586g; 17, interior of a small, flat pedicle valve with part of the brachial valve in place and having angustilobate lobes, the flatness due to cementation to *Isogramma*,  $\times 1$ , hypotype USNM 153586j; 18, ventral side of the same specimen, showing the ornament of *Isogramma* impressed on the *Eolyttonia*,  $\times 1.5$ ; 19-21, ventral side and interior views of another conical pedicle valve, preserving the strongly papillose brachial valve,  $\times 1$ , hypotype USNM 153586i; 22-24, side, posterior, and interior views of a broadly conical specimen, with tight angustilobate lobes and large cowl,  $\times 1$ , hypotype USNM 153586k; 25, a large, broadly shallow specimen with the pustulose brachial valve in place and a short cowl,  $\times 1$ , hypotype USNM 153586-1 [Bone Spring Formation (lower), locality USNM 728e].

PLATE 140.—*Eolyttonia*.



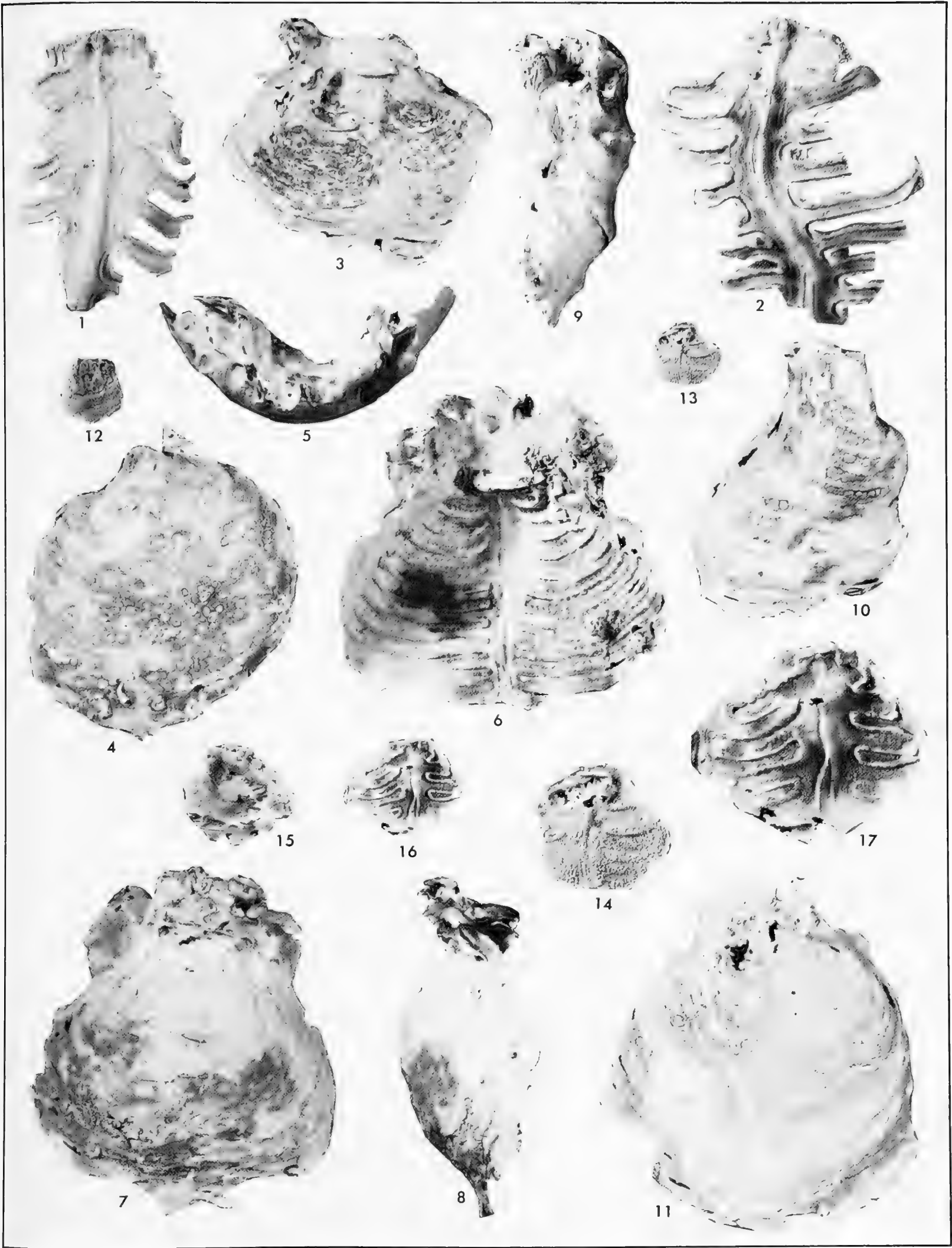
## PLATE 141

*Eolyttonia*

*Eolyttonia chaotica*, new species: 1, 2, Interior views of axial portions of two brachial valves,  $\times 2$ , paratype USNM 153621a; b; 3, interior of a small pedicle valve with angustilobate septa,  $\times 1$ , paratype USNM 150649i; 4, exterior of another pedicle valve,  $\times 1$ , paratype USNM 150649b (for an additional view, see Plate 143: figure 13); 5–8, posterior, interior, ventral, and side views of a large pedicle valve, with angustilobate lobes,  $\times 1$ , holotype USNM 140649c; 9, 10, side and ventral views of a distorted specimen,  $\times 1$ , paratype USNM 150649e; 11, ventral view of a large pedicle valve,  $\times 1$ , paratype USNM 150649g (for additional views of this specimen, see Plate 142: figures 11, 12) [Road Canyon Formation, locality USNM 721o].

12, 13, Exterior and interior of an immature pedicle valve,  $\times 1$ , paratype USNM 153619a; 14, interior of the preceding specimen enlarged, showing angustilobate lobes,  $\times 2$ ; 15, 16, exterior and interior of another larger but immature specimen,  $\times 1$ , paratype USNM 153619b; 17, enlargement of the interior of the preceding to show the immature (latilobate) lobes,  $\times 2$  [Road Canyon Formation, locality USNM 702c].

PLATE 141.—*Eolyttonia*.





## PLATE 142

*Eolyttonia*

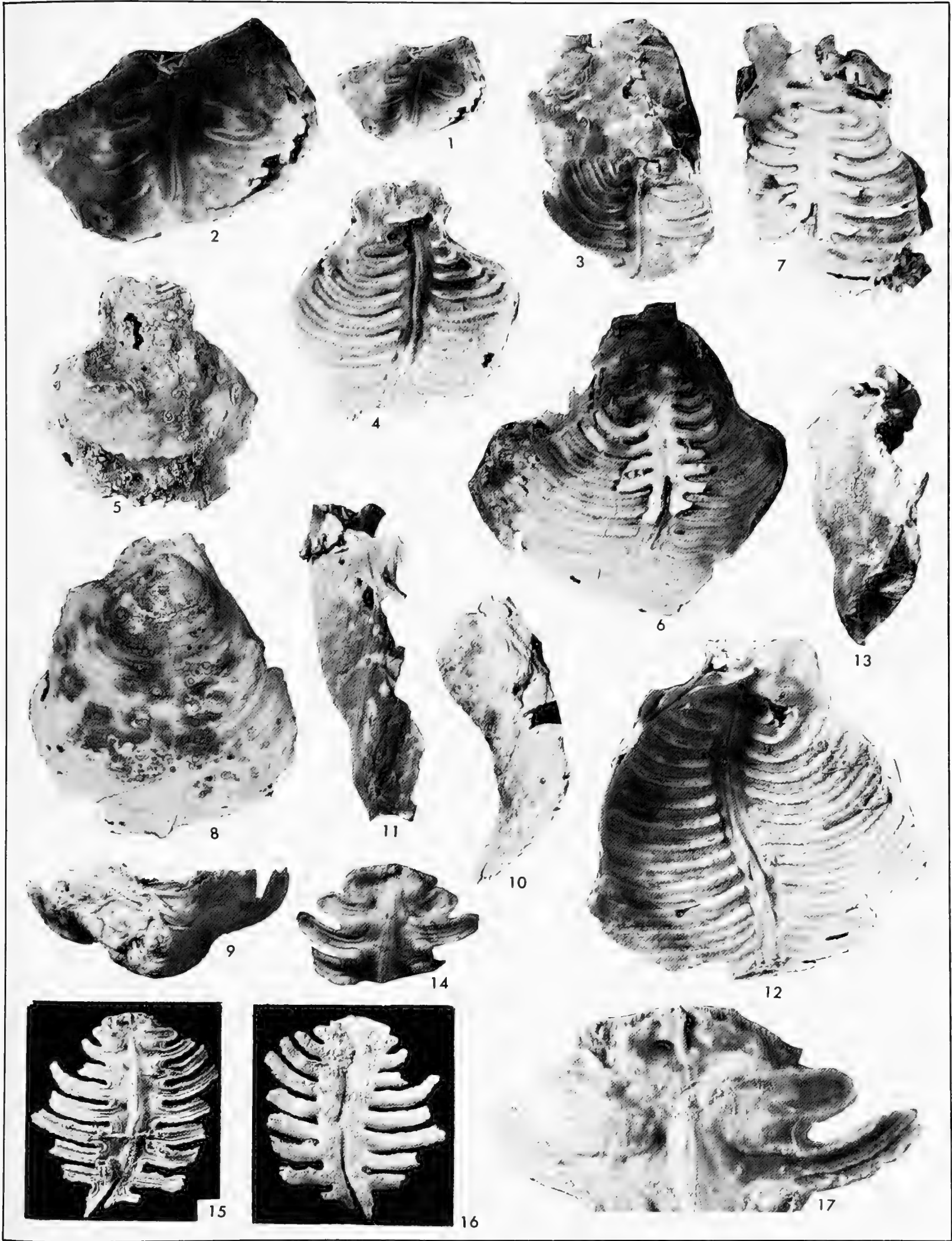
*Eolyttonia chaotica*, new species: 1, 2, Interior view of a small pedicle valve starting life inside the cavity of a productid brachial valve and having an incomplete vallum with posteriorly angustilobate median ridge,  $\times 1$ ,  $\times 2$ , paratype USNM 153619c; 3, a larger pedicle valve attached to one of its fellow *Eolyttonia*,  $\times 1$ , paratype USNM 153619d; 4, 5, interior and exterior of a still larger pedicle valve with angustilobate lobes,  $\times 1$ , paratype USNM 153619e; 14, posterior part of brachial valve, showing cardinal process,  $\times 2$ , paratype USNM 150644a [Road Canyon Formation, locality USNM 702c].

6, Dorsal view of a specimen with part of the brachial valve preserved in place,  $\times 1$ , paratype USNM 153622 [Road Canyon Formation, locality USNM 719x].

7, Fragment of a specimen, showing brachial valve in place,  $\times 1$ , paratype USNM 150649j; 8-10, ventral, posterior, and side views of a pedicle valve,  $\times 1$ , paratype USNM 150649a; 11, 12, side and interior views of a large pedicle valve with hood,  $\times 1$ , paratype USNM 150649g (for an additional view of this specimen, see Plate 141: figure 4); 13, side view,  $\times 1$ , paratype 150649b [Road Canyon Formation, locality USNM 721o].

15, 16, Interior and exterior of a brachial valve,  $\times 1$ , paratype USNM 153620; 17, posterior of the preceding specimen enlarged to show the small single-shafted bilobed cardinal process,  $\times 3$  [Road Canyon Formation, locality USNM 721s].

PLATE 142.—*Eolyttonia*.



## PLATE 143

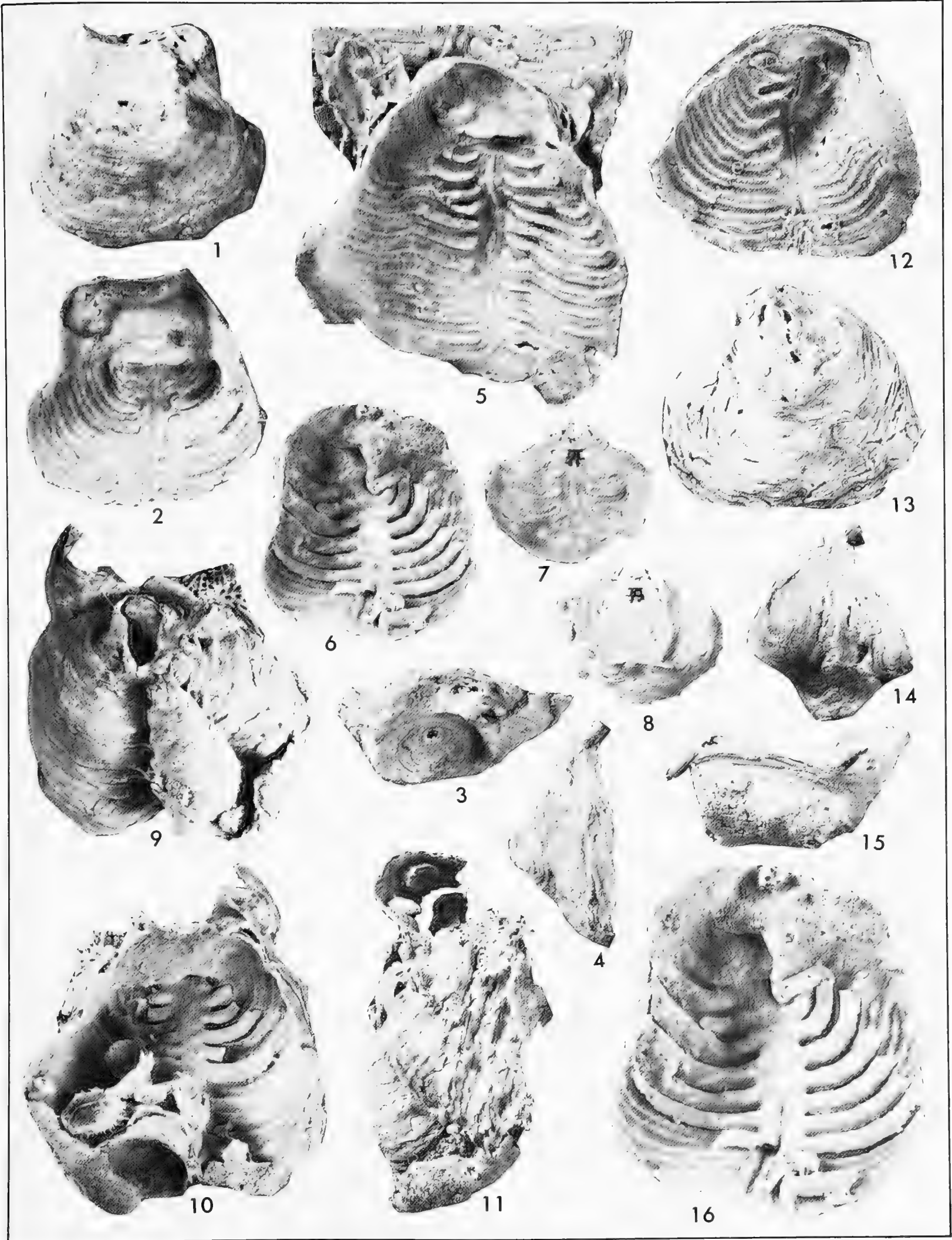
*Eolyttonia*

*Eolyttonia circularis*, new species: 1-4, Ventral, interior, posterior, and side views of a specimen with unusually large cowl,  $\times 1$ , paratype USNM 150723e; 5, interior of a large specimen attached to *Collemataria*,  $\times 1$ , paratype USNM 153616a; 7, 8, interior and exterior views of a youthful specimen with wide angustilobate lobes,  $\times 1$ , paratype USNM 153616b; 14, 15, side and posterior views of small, deep pedicle valve,  $\times 1$ , paratype USNM 150723f (for additional views, see Plate 144: figures 8, 9) [Cathedral Mountain Formation, locality USNM 702a<sup>1</sup>].

6, Dorsal view of a specimen preserving both valves,  $\times 1$ , paratype USNM 154530; 16, same view as preceding, showing details of the brachial valve,  $\times 1.5$ ; 12, 13, interior and exterior views of a moderately deep specimen, showing angustilobate lobes,  $\times 1$ , paratype USNM 150650 [Cathedral Mountain Formation, locality USNM 702].

9-11, Ventral, dorsal, and side views of a nearly complete specimen partially deformed by growth against *Hercosia*,  $\times 1$ , holotype USNM 150727 [Cathedral Mountain Formation, locality USNM 702un].

PLATE 143.—*Eolyttonia*.



## PLATE 144

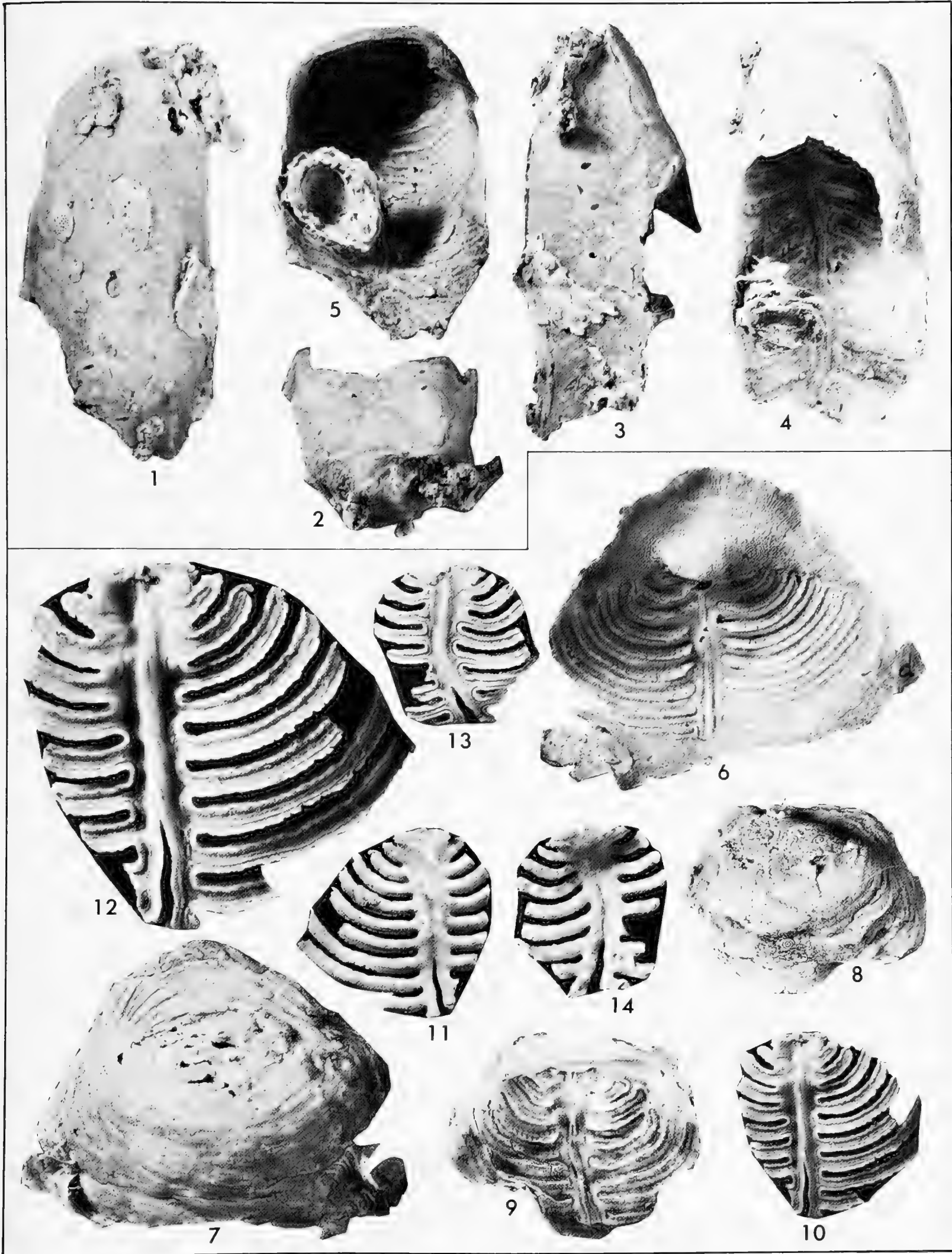
*Eolyttonia*

*Eolyttonia fredericksi* (R. E. King): 1-4, Ventral, posterior, side, and dorsal views of long slender specimen with angustilobate lobes and long cowl, hypotype USNM 150673; 5, the preceding specimen tilted to show interior,  $\times$  1 [Neal Ranch Formation (beds 12-14 of P. B. King), locality USNM 701h].

*Eolyttonia circularis*, new species: 6, 7, Interior and ventral views of a large specimen with well-developed cowl and thickened lobes,  $\times$  1, paratype USNM 150721d; 8, 9, ventral and dorsal views of a small pedicle valve-with angustilobate lobes,  $\times$  1, paratype USNM 150723f (for additional views, see Plate 143: figures 14, 15); 10, 11, interior and exterior of a brachial valve,  $\times$  1, paratype USNM 153616c; 12, interior of preceding to show cardinal process and fluted lobes,  $\times$  2; 13, 14, interior and exterior of another brachial valve,  $\times$  1, paratype USNM 150723g [Cathedral Mountain Formation, locality USNM 702a<sup>1</sup>].



PLATE 144.—*Eolyttonia*.



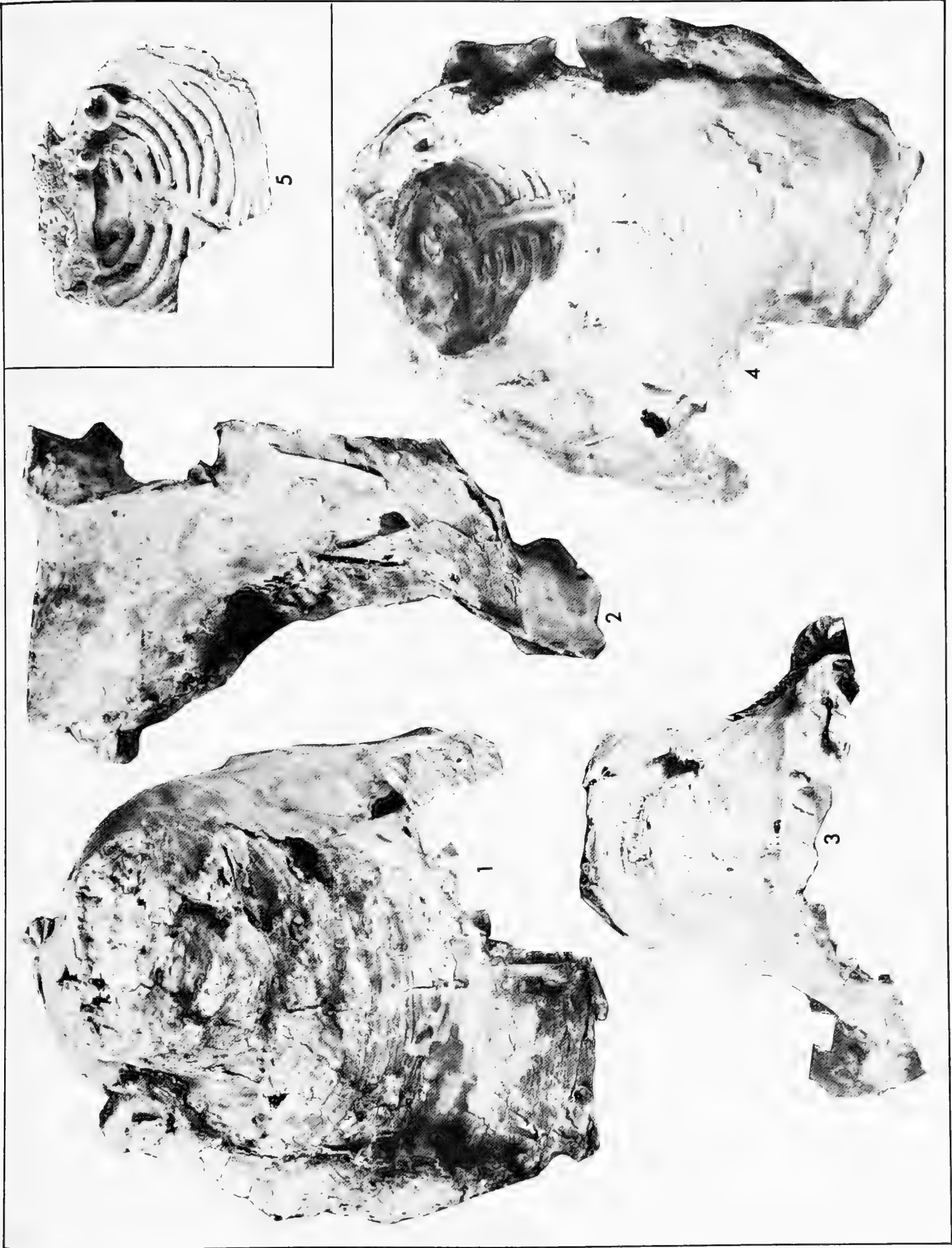
## PLATE 145

*Eolyttonia*

*Eolyttonia catilla*, new species: 1–4, Ventral, side, posterior, and interior views of a large specimen with short cowl but angustilobate lobes,  $\times 1$ , paratype USNM 153583 [Neal Ranch Formation (bed 12 of P. B. King), locality USNM 701c].

*Eolyttonia circularis*, new species: 5, Specimen with short cowl, in dorsal view,  $\times 1$ , paratype USNM 153585 [Cathedral Mountain Formation, locality USNM 702].

PLATE 145.—*Eolyttonia*.



**PLATE 146***Eolyttonia*

*Eolyttonia cornucopia*, new species: 1–3, Dorsal, interior, and side views of a pair of attached specimens,  $\times 1$ , paratype USNM 150627b; 4–6, dorsal, interior, and ventral views of a single specimen, showing details of the inner narrowly angustilobate to solidilobate lobes,  $\times 1$ , holotype USNM 150627c [Skinner Ranch Formation (lower), locality USNM 720e].

PLATE 146.—*Eolyttonia*.



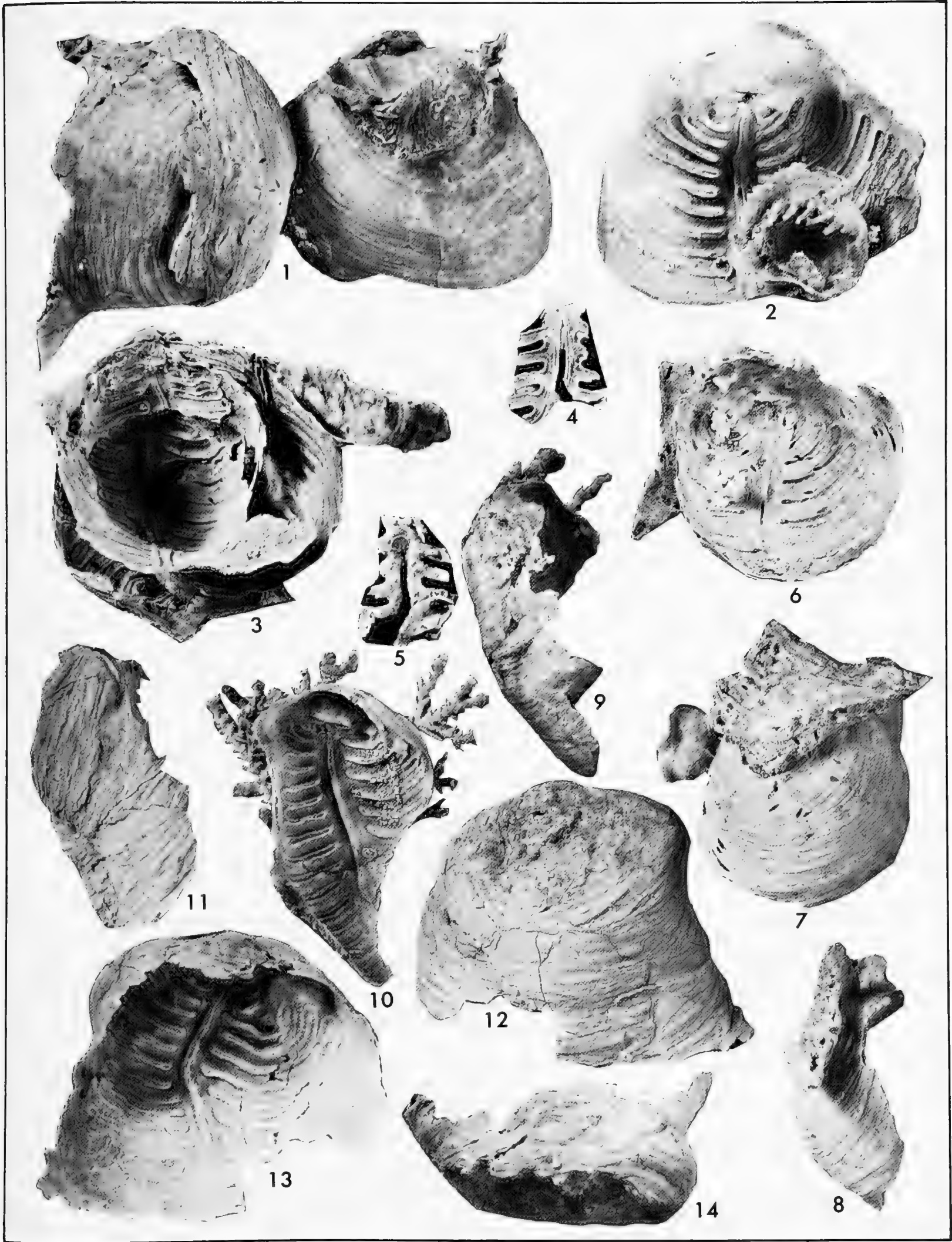


## PLATE 147

*Eolyttonia*

*Eolyttonia fredericki* (R. E. King): 1, Cluster of specimens seen from the ventral side,  $\times 1$ , hypotype USNM 153618a; 2, interior of the specimen on the right side of the cluster in the preceding view, showing angustilobate lobes with attached *Teguliferina*,  $\times 1$ ; 3, interior of specimen on left side of the cluster,  $\times 1$ ; 4, 5, interior and exterior of part of a brachial valve,  $\times 1$ , hypotype USNM 150669c; 6–8, interior, ventral, and side views of a small pedicle valve with latilobate to angustilobate lobes,  $\times 1$ , hypotype USNM 153618b; 9, 10, side and interior views of a long, narrow pedicle valve, with angustilobate lobes,  $\times 1$ , hypotype USNM 150669a; 11–14, side, ventral, interior, and posterior views of a large pedicle valve with well-developed cowl and with angustilobate lobes,  $\times 1$ , hypotype USNM 150669b [Neal Ranch Formation (beds 12–14 of P. B. King), locality USNM 701c].

PLATE 147.—*Eolyttonia*.



## PLATE 148

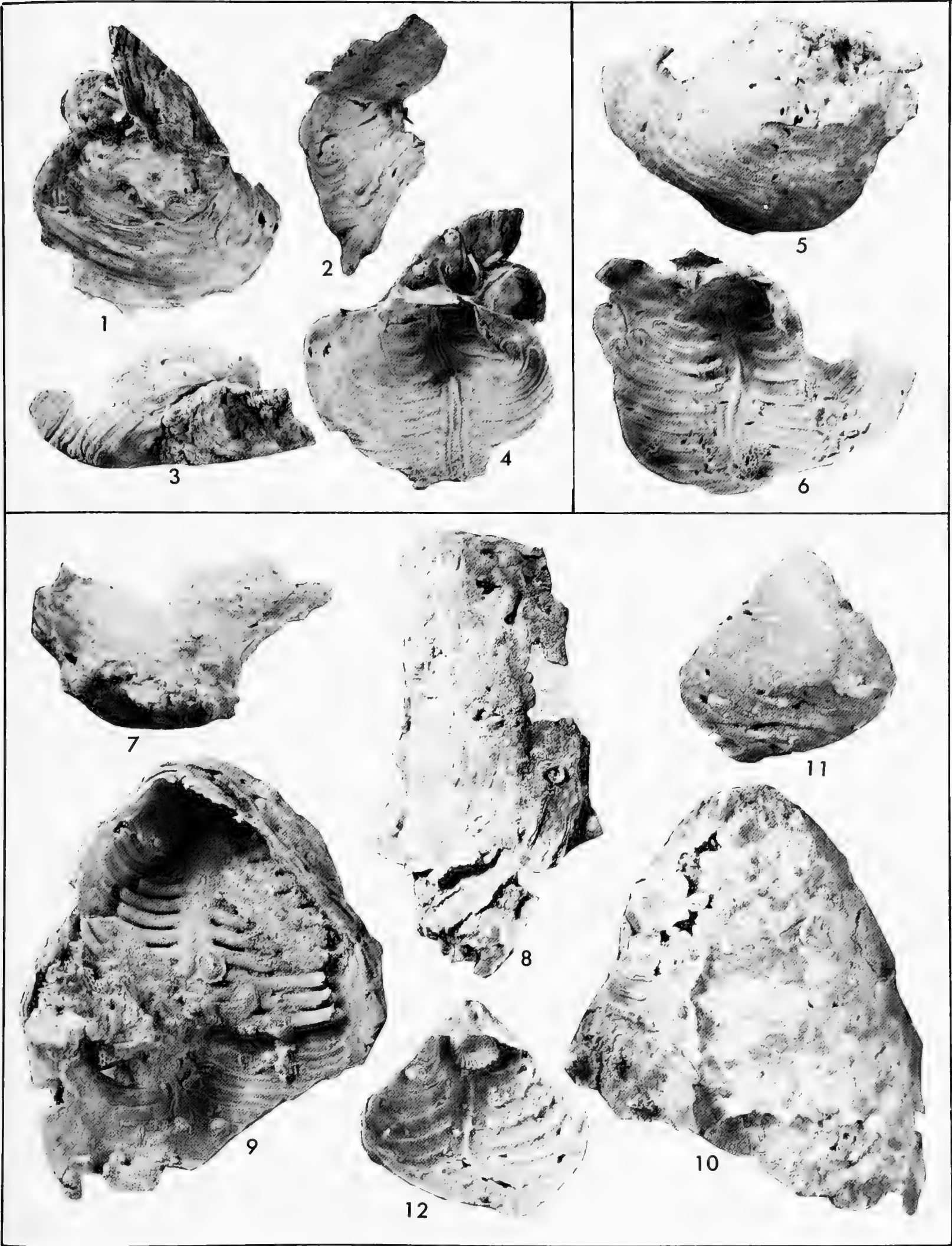
*Eolyttonia*

*Eolyttonia fredericksi* (R. E. King): 1–4, Ventral, side, posterior, and interior views of a small pedicle valve,  $\times 1$ , hypotype USNM 153617a [Neal Ranch Formation (beds 12–14 of P. B. King), locality USNM 701h].

5, 6, Ventral and interior views of medium-sized specimen with angustilobate lobes,  $\times 1$ , hypotype USNM 150670c [Neal Ranch Formation, (beds 12–14 of P. B. King), locality USNM 701c].

*Eolyttonia gigantea*, new species: 7–10, Posterior, side, dorsal, and ventral views of a large complete specimen,  $\times 1$ , paratype USNM 153615a; 11, 12, ventral and interior views of a small pedicle valve with attached *Diplanus* and with latilobate lobes,  $\times 1$ , paratype USNM 153615e [Cibolo Formation (Breccia Zone of Udden), locality USNM 728–1].

PLATE 148.—*Eolyttonia*.



**PLATE 149***Eolyttonia*

*Eolyttonia gigantea*, new species: 1–4, Posterior, interior, dorsal, and side views of a large conical specimen with large cowl,  $\times 1$ , paratype USNM 153579a; 5, dorsal view of a smaller specimen with large cowl and angustilobate lobes,  $\times 1$ , paratype USNM 153579b; 6–9, dorsal, posterior, interior, and side views of a large flattened specimen with large cowl and solidiseptate lobes,  $\times 1$ , paratype USNM 153579c [Skinner Ranch Formation (lower), locality USNM 720e].



PLATE 149.—*Eolyttonia*.



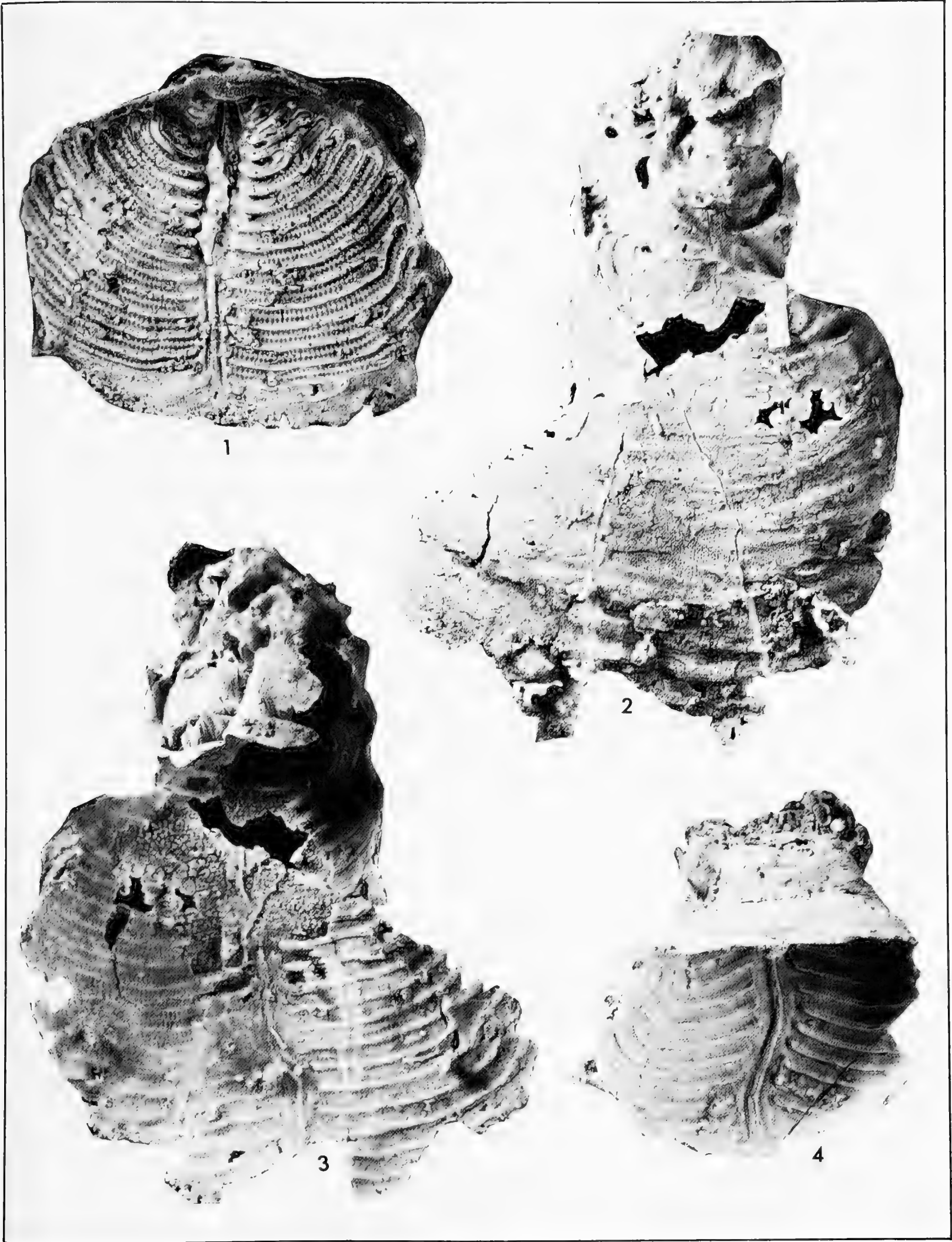
**PLATE 150***Eolyttonia*

*Eolyttonia gigantea*, new species: 1, Interior of a well-rounded pedicle valve, showing the lateral grooves and their markings,  $\times 1$ , paratype USNM 150632a [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

2, 3, Exterior and interior of an exceptionally large specimen with solidiseptate lobes,  $\times 1$ , paratype USNM 150634 [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 707g].

4, Dorsal view of a medium-sized specimen showing cowl and inner details of angustilobate lobes,  $\times 1$ , paratype USNM 150641a [Skinner Ranch Formation (lower), locality USNM 720e].

PLATE 150.—*Eolyttonia*.

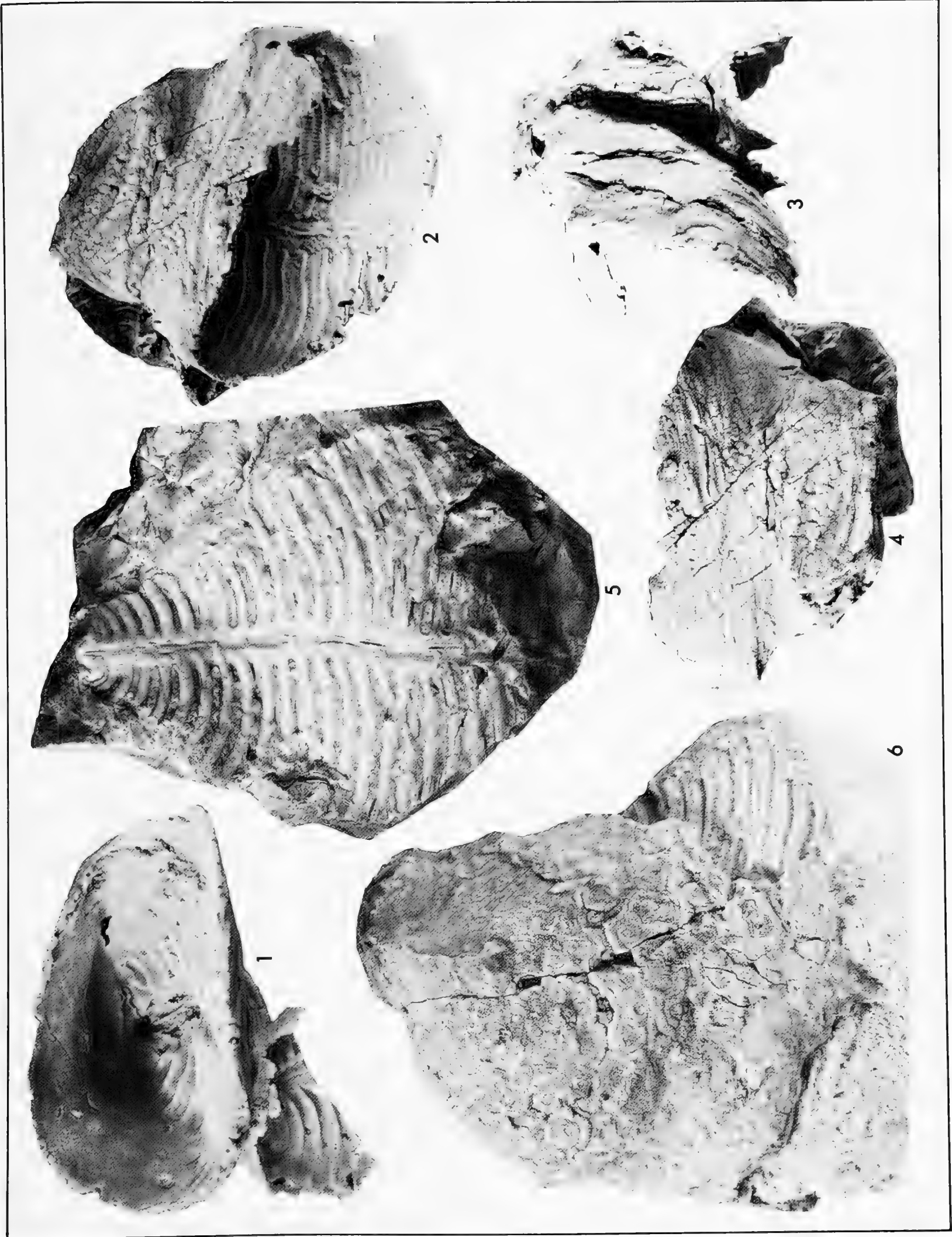


**PLATE 151***Eolyttonia*

*Eolyttonia gigantea*, new species: 1–4, Interior, ventral, side, and posteroventral views of a specimen preserving the cowl and showing the attachment surface and solidisepta,  $\times 1$ , paratype USNM 150642 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 732b].

5, Exterior of a large brachial valve,  $\times 1$ , paratype USNM 150632b; 6, ventral view of a large specimen,  $\times 1$ , paratype USNM 153578 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

PLATE 151.—*Eolyttonia*.



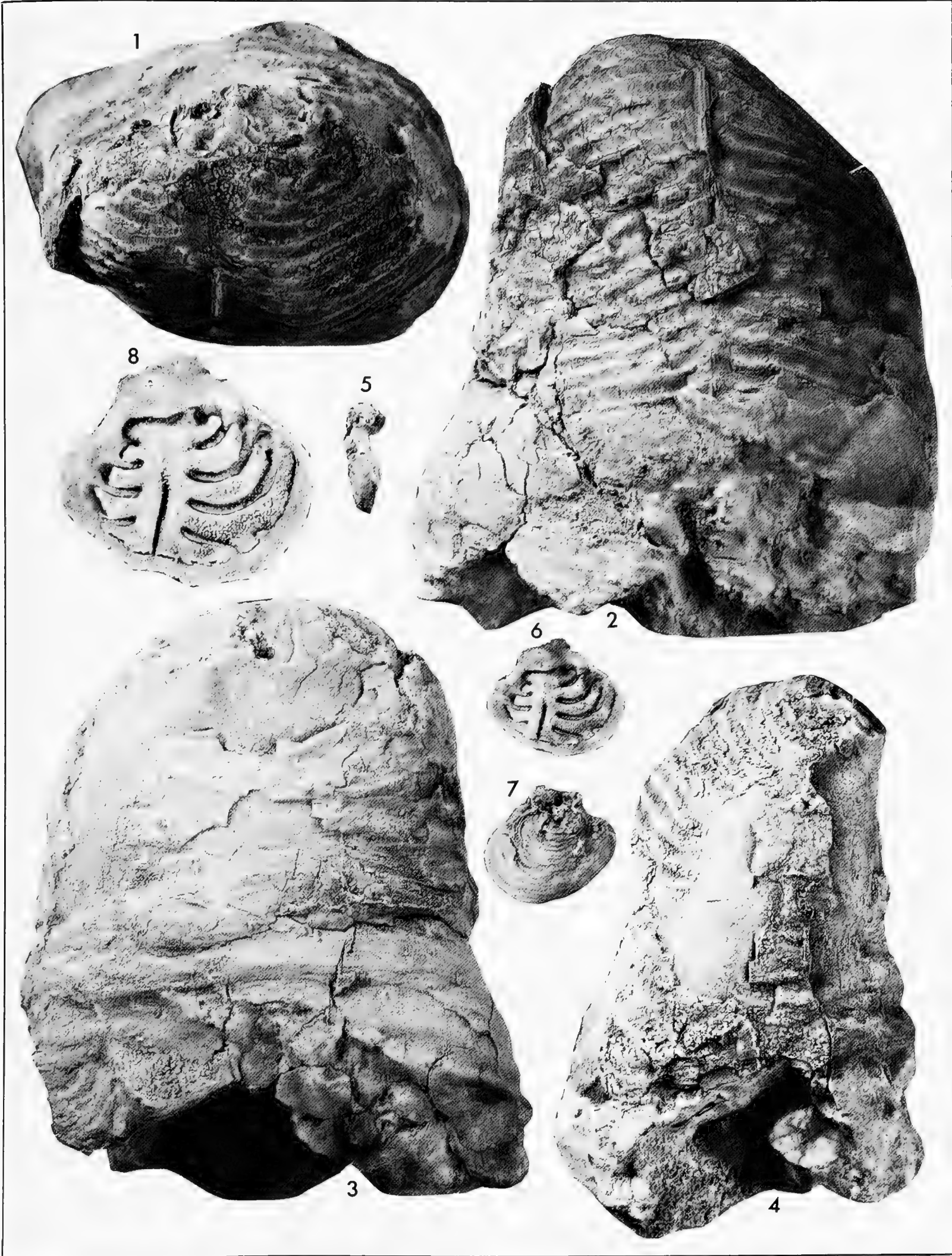


**PLATE 152***Eolyttonia* and *Loxophragmus*

*Eolyttonia gigantea*, new species: 1–4, Posterior, ventral, dorsal, and side views of a large, partially exfoliated specimen with exceptionally long cowl (figure 3), showing details of the pedicle valve interior,  $\times 1$ , holotype USNM 150640d [Skinner Ranch Formation (Decie Ranch Member), locality USNM 714t].

*Loxophragmus ellipticus*, new species: 5–7, Side, dorsal, and ventral views of a complete specimen,  $\times 1$ , paratype USNM 150727; 8, dorsal view of the preceding specimen,  $\times 2$  [Cathedral Mountain Formation, locality USNM 702un].

PLATE 152.—*Eolyttonia* and *Loxophragmus*.

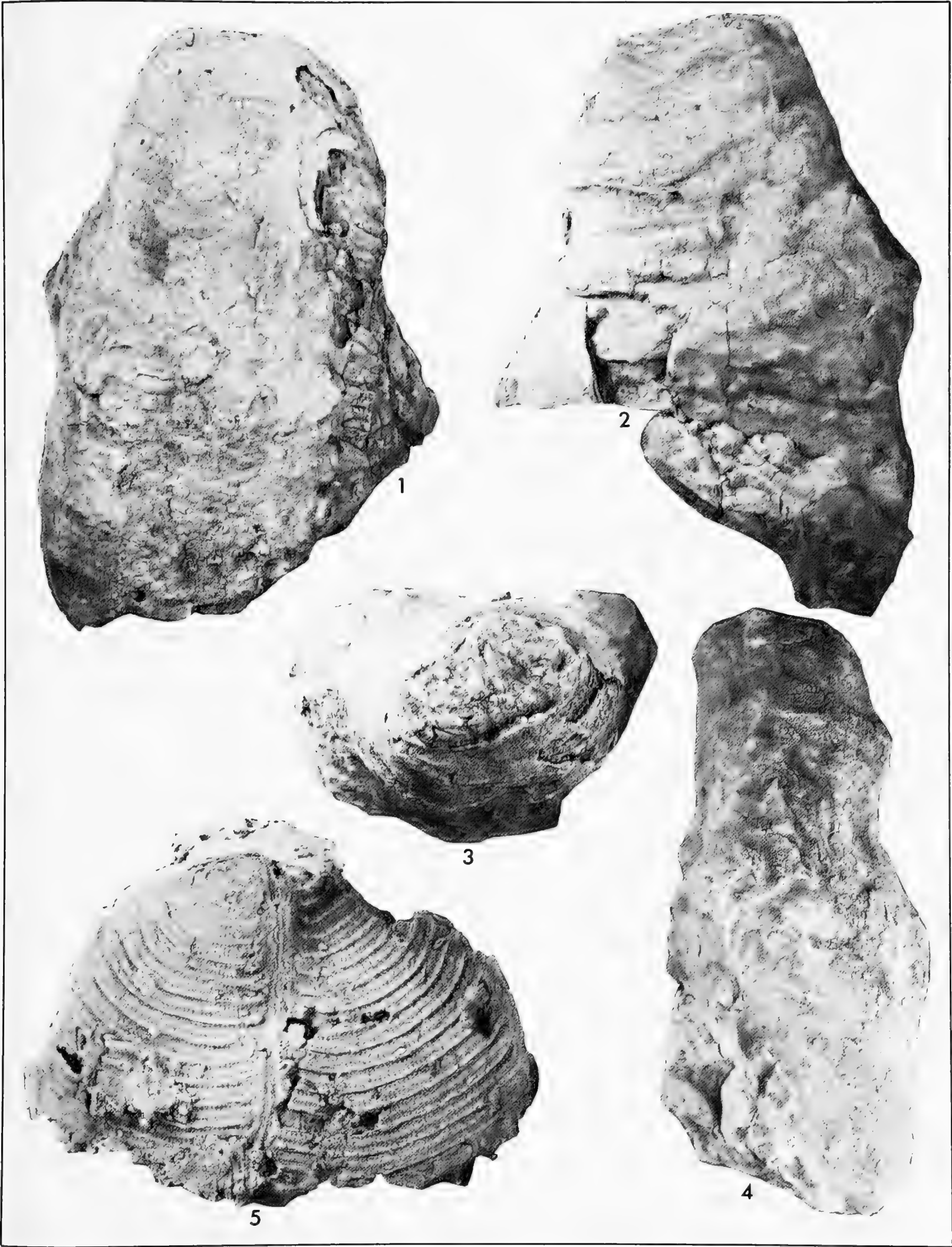


**PLATE 153***Eolyttonia*

*Eolyttonia gigantea*, new species: 1–4, Ventral, dorsal, posterior, and side views of a narrow specimen with long cowl,  $\times$  1, paratype USNM 150640b [Skinner Ranch Formation (Decie Ranch Member), locality USNM 714t].

5, Interior of a large pedicle valve with solidisepta,  $\times$  1, paratype USNM 150633 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

PLATE 153.—*Eolyttonia*.



## PLATE 154

*Eolyttonia*, *Collemataria*, *Liosotella*, and *Chonetinella*

*Eolyttonia gigantea*, new species: 1–4, Interior, posterior, side, and dorsal views of a septivallate specimen preserving the cowl,  $\times$  1, paratype USNM 153571 [Cibolo Formation (Breccia Zone of Udden), locality USNM 728–1].

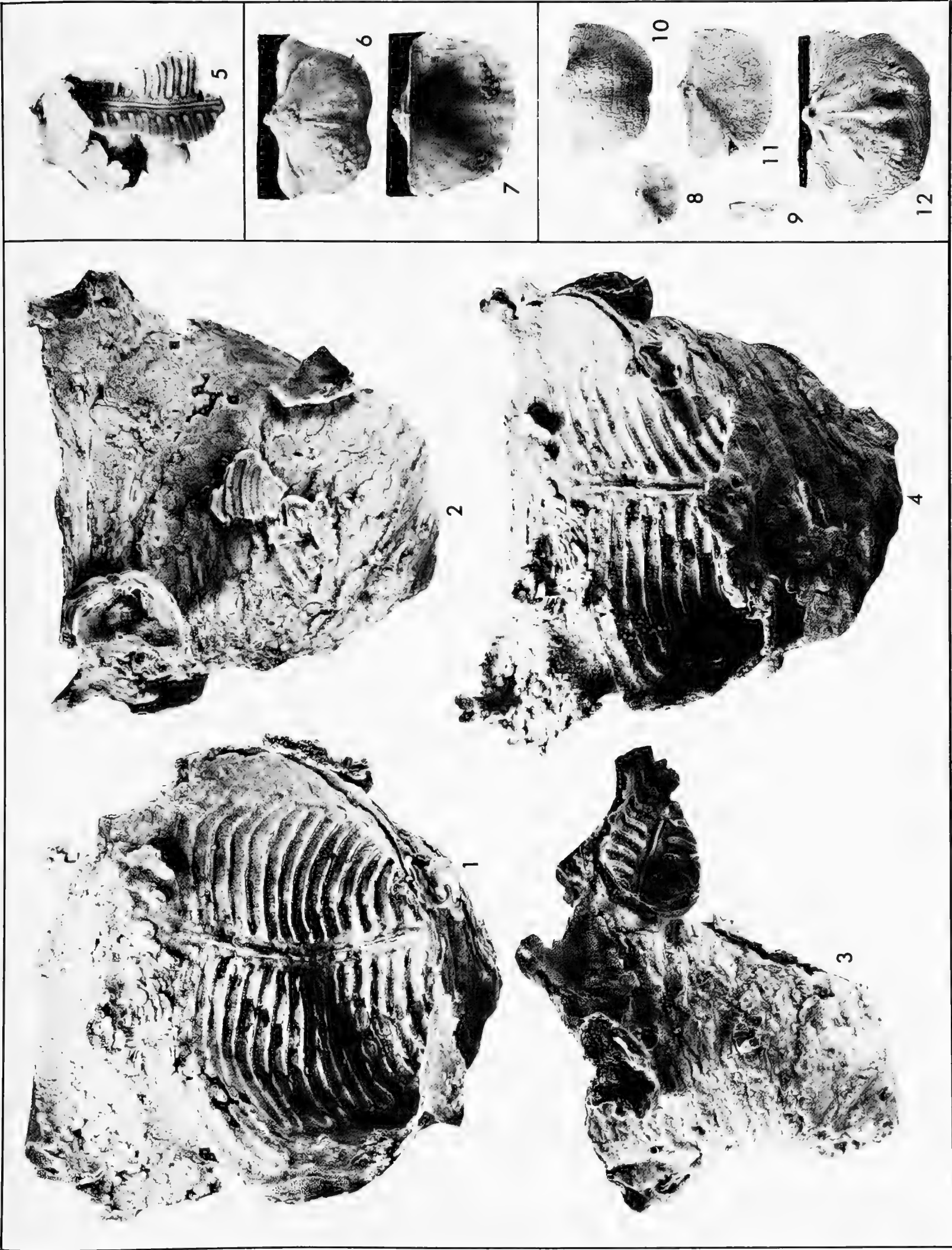
*Collemataria spatulata*, new species: 5, Dorsal view of a small cluster, showing the interior of a pedicle valve,  $\times$  1, paratype USNM 153570 [Bell Canyon Formation (Lamar Member), locality USNM 728p].

*Liosotella rotunda*, new species: 6, 7, Interior and exterior of the brachial valve,  $\times$  2, paratype USNM 155036b [Road Canyon Formation, locality USNM 736x].

*Chonetinella gerontica*, new species: 8, 9, Dorsal and side views of a complete specimen,  $\times$  1, paratype USNM 154417c; 10, 11 ventral and dorsal views of the preceding specimen,  $\times$  2; 12, interior of the brachial valve,  $\times$  2, paratype USNM 154417b [Road Canyon Formation, locality USNM 732j].



PLATE 154.—*Eolyttonia*, *Collemataria*, *Liosotella*, and *Chonetinella*.



## PLATE 155

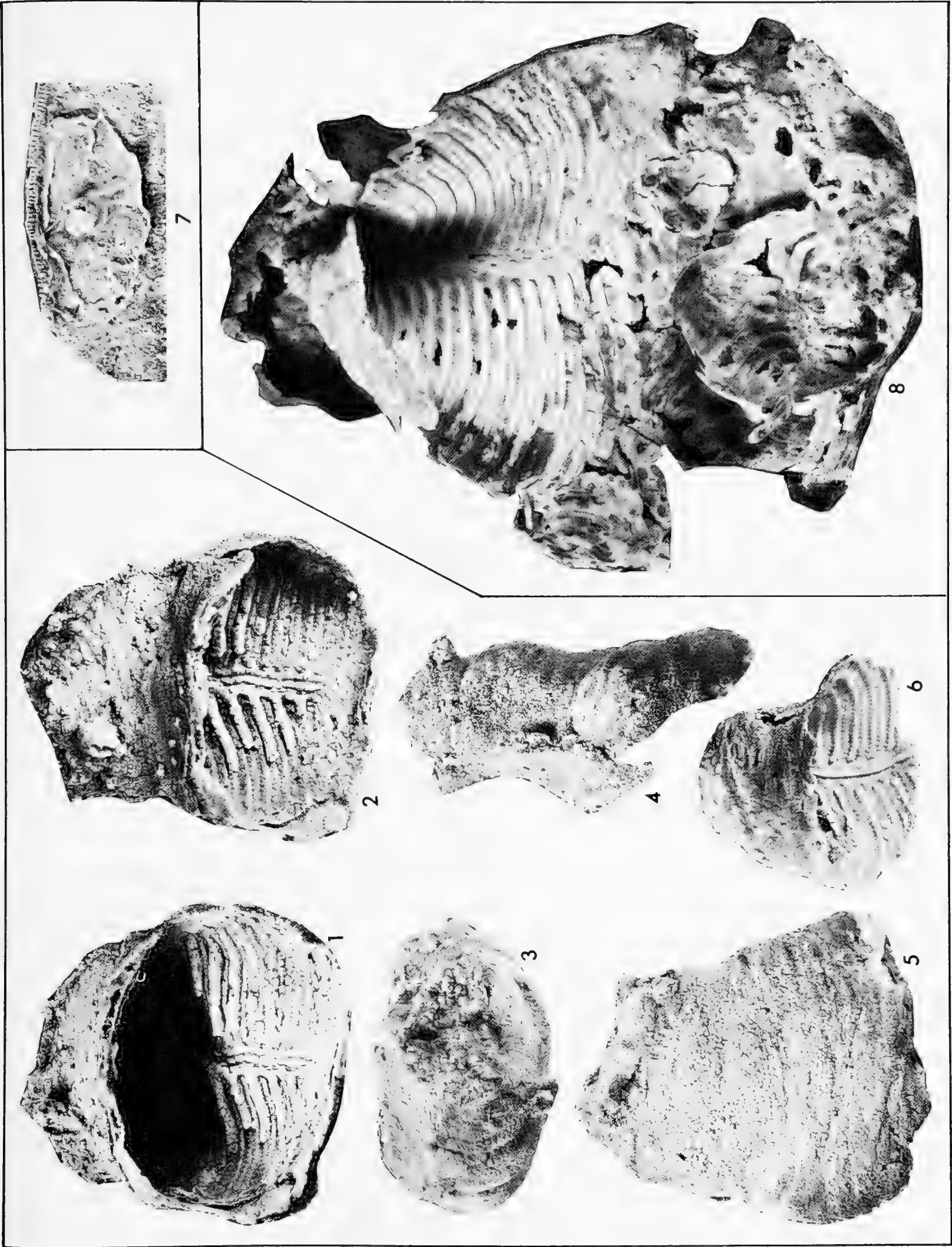
*Eolyttonia* and *Poikilosakos*

*Eolyttonia gigantea*, new species: 1–5, Interior, dorsal, posterior, side, and ventral views of a small specimen with large cowl, showing remnants of the brachial valve,  $\times$  1, paratype USNM 153579d; 6, dorsal view of a small conical specimen,  $\times$  1, paratype USNM 153579e [Skinner Ranch Formation (lower), locality USNM 720e].

*Poikilosakos* species 2: 7, Typical specimen, showing eccentric muscle scar,  $\times$  2, figured specimen USNM 153581a [Word Formation (Willis Ranch Member), locality USNM 706e].

*Eolyttonia gigantea*, new species: 8, Unusually large septivallate specimen, showing the interior of the pedicle valve,  $\times$  1, paratype USNM 153580 [Cibolo Formation (Breccia Zone of Udden), locality USNM 728–1].

PLATE 155.—*Eolyttonia* and *Poikilosakos*.



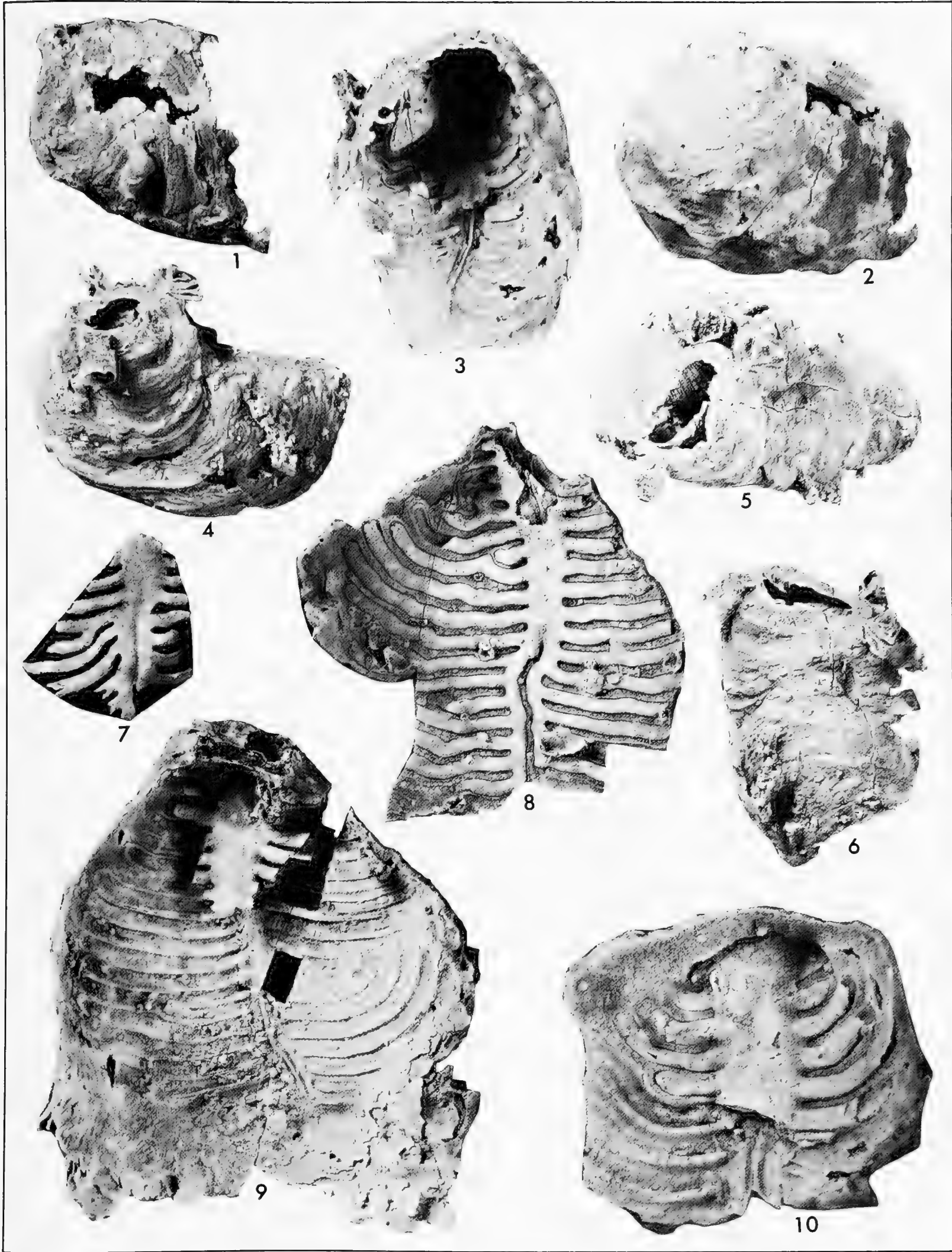
## PLATE 156

*Eolyttonia*

*Eolyttonia gigantea*, new species: 1, 2, Side and ventral views of a small, deep individual,  $\times 1$ , paratype USNM 153615b; 3-6, dorsal, ventral, posterior, and side views of a distorted specimen, preserving part of the brachial valve,  $\times 1$ , paratype USNM 153615g; 7, exterior of a small brachial valve,  $\times 1$ , paratype USNM 153615f; 8, dorsal view of a large but imperfect specimen, showing the brachial valve,  $\times 1$ , paratype USNM 153615h; 9, dorsal view of a large septivallate pedicle valve with the axial part of the posterior of the brachial valve in place,  $\times 1$ , paratype USNM 153615d (this specimen on the observer's right, at midvalve, shows a repaired injury); 10, posterior part of a specimen with parts of both valves in place, showing the articulation,  $\times 2$ , paratype USNM 153615c [Cibolo Formation (Breccia Zone of Udden), locality USNM 728-1].



PLATE 156.—*Eolyttonia*.



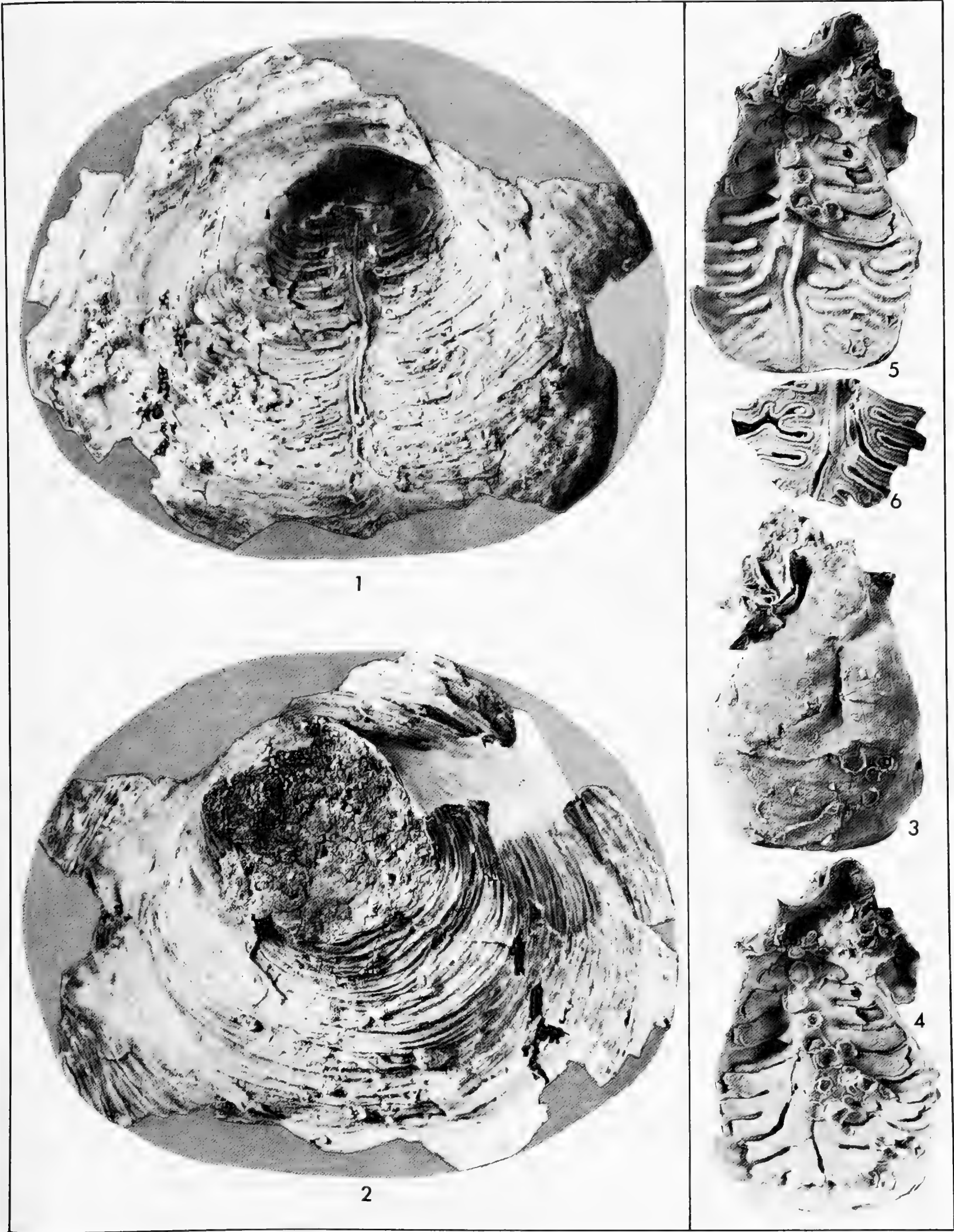


**PLATE 157***Eolyttonia* and *Collemataria*

*Eolyttonia catilla*, new species: 1, 2, Interior and exterior views of an exceptionally large and shallow pervivallate specimen,  $\times 1$ , holotype USNM 153584 [Neal Ranch Formation (Bed 12 of P. B. King), locality USNM 701c].

*Collemataria americana* (Girty): 3, 4, Exterior and dorsal views of a specimen preserving the brachial valve in place and partially covered by spat of *Acritosia* or *Teguliferina*,  $\times 1$ , hypotype USNM 153582; 5, same specimen with part of the brachial valve removed to show the thick anterior angustiseptate lobes,  $\times 1$ ; 6, interior of the part of the brachial valve removed to show details of the lateral lobes,  $\times 1$  [Bone spring Formation (lower), locality USNM 728e].

PLATE 157.—*Eolyttonia* and *Collemataria*.



## PLATE 158

*Eolyttonia*

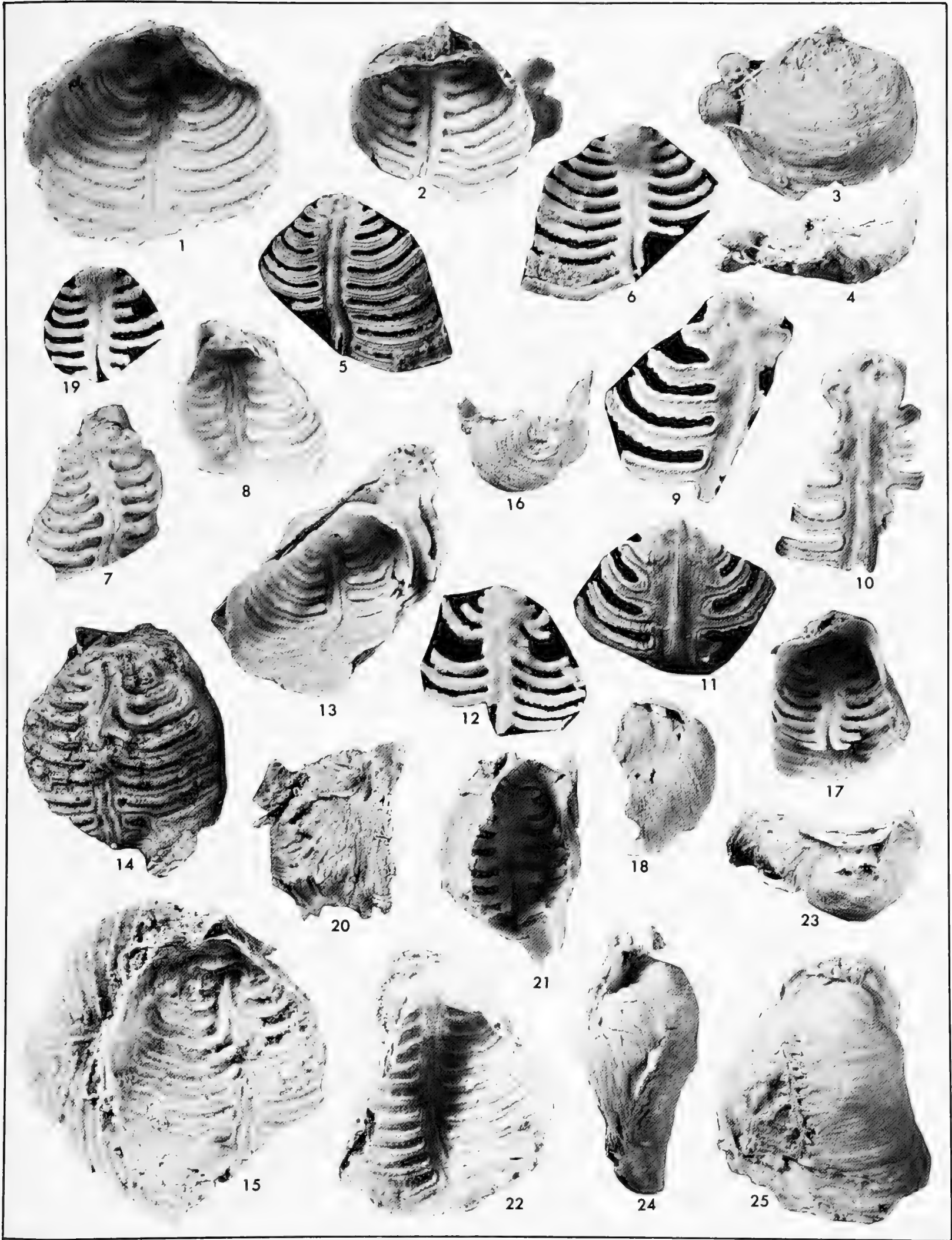
*Eolyttonia pocillata*, new species: 1, Interior of a pedicle with well-developed hood,  $\times$  1, paratype USNM 150651a; 2-4, dorsal, ventral, and posterior views of a well-rounded cowed individual,  $\times$  1, holotype USNM 150651b; 14, 15, another internal mould and the specimen from which it was prepared,  $\times$  1,  $\times$  1.5, paratype USNM 153624 [Cathedral Mountain Formation, locality USNM 702].

7, 8, Interior of a small pedicle valve and the latex impression made from it, showing lateral lobes,  $\times$  1, paratype USNM 153623 [Cathedral Mountain Formation, locality AMNH 500F = USNM 702].

5, 6, Interior and exterior of a brachial valve,  $\times$  1, paratype USNM 150653-1; 9-11, brachial valve interior, showing cardinal process and fluted lobes  $\times$  2, paratypes USNM 150653q-s; 12, exterior of another brachial valve, showing irregular growth of lobes,  $\times$  1, paratype USNM 150653o; 13, pedicle valve attached to brachial valve of *Xestosia*,  $\times$  1, paratype USNM 150653k; 16-18, posterior, dorsal, and side views of a deep individual,  $\times$  1, paratype USNM 150653b; 19, exterior of the brachial valve taken from the preceding,  $\times$  1; 22-25, dorsal, posterior, side, and ventral views of a large pedicle valve with solidisepta and cowl,  $\times$  1, paratype USNM 150654 [Cathedral Mountain Formation, locality USNM 702b].

20, 21, Side and dorsal views of another very deep specimen,  $\times$  1, paratype USNM 150658b [Cathedral Mountain Formation, locality USNM 702un].

PLATE 158.—*Eolyttonia*.



**PLATE 159***Eolyttonia*

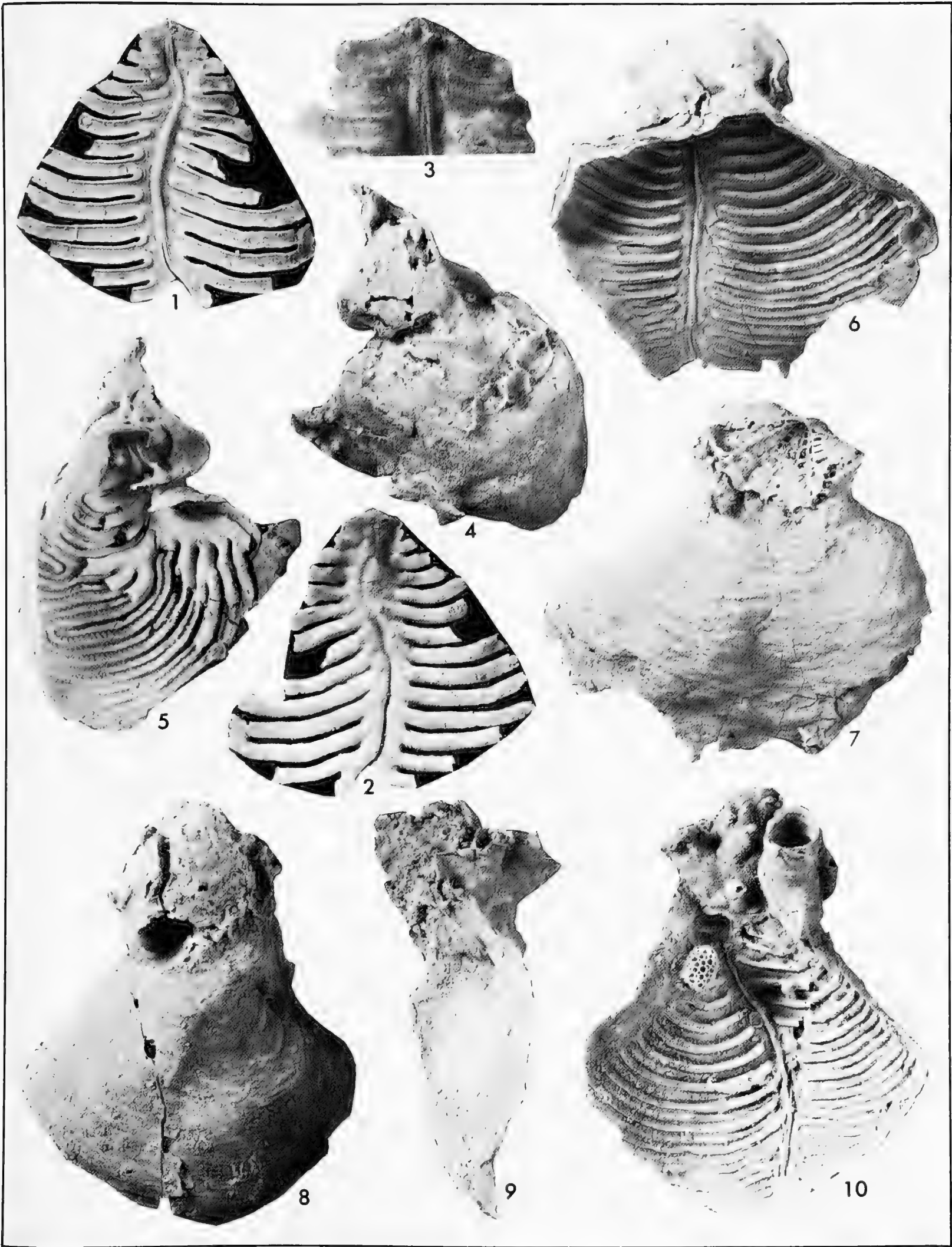
*Eolyttonia progressa*, new species: 1, 2, Interior and exterior of a large brachial valve,  $\times$  1, paratype USNM 150739c; 3, posterior of the preceding specimen, showing cardinal process,  $\times$  3 [Word Formation (Appel Ranch Member), locality USNM 715j].

4, 5, Ventral and interior views of specimen with greatly distorted interior,  $\times$  1, paratype USNM 151311b; 6, 7, interior and exterior of a large septivallate pedicle valve,  $\times$  1, paratype USNM 151311c [Word Formation (Appel Ranch Member), locality USNM 719z].

8–10, Ventral, side, and dorsal views of another large septivallate pedicle valve,  $\times$  1, paratype USNM 153625, with cowl aborted by attached bryozoa [Word Formation (Appel Ranch Member), locality USNM 722t].



PLATE 159.—*Eolyttonia*.



## PLATE 160

*Eolyttonia*

*Eolyttonia* species 1: 1, Interior of a pedicle valve attached within the brachial valve of *Peniculauris*, showing angulisepta,  $\times$  1, figured specimen USNM 150788 [Hess Formation (Taylor Ranch Member), locality USNM 702m].

2, Exterior of the brachial valve,  $\times$  1, figured specimen USNM 153627 [Hess Formation (Taylor Ranch Member), locality USNM 716o].

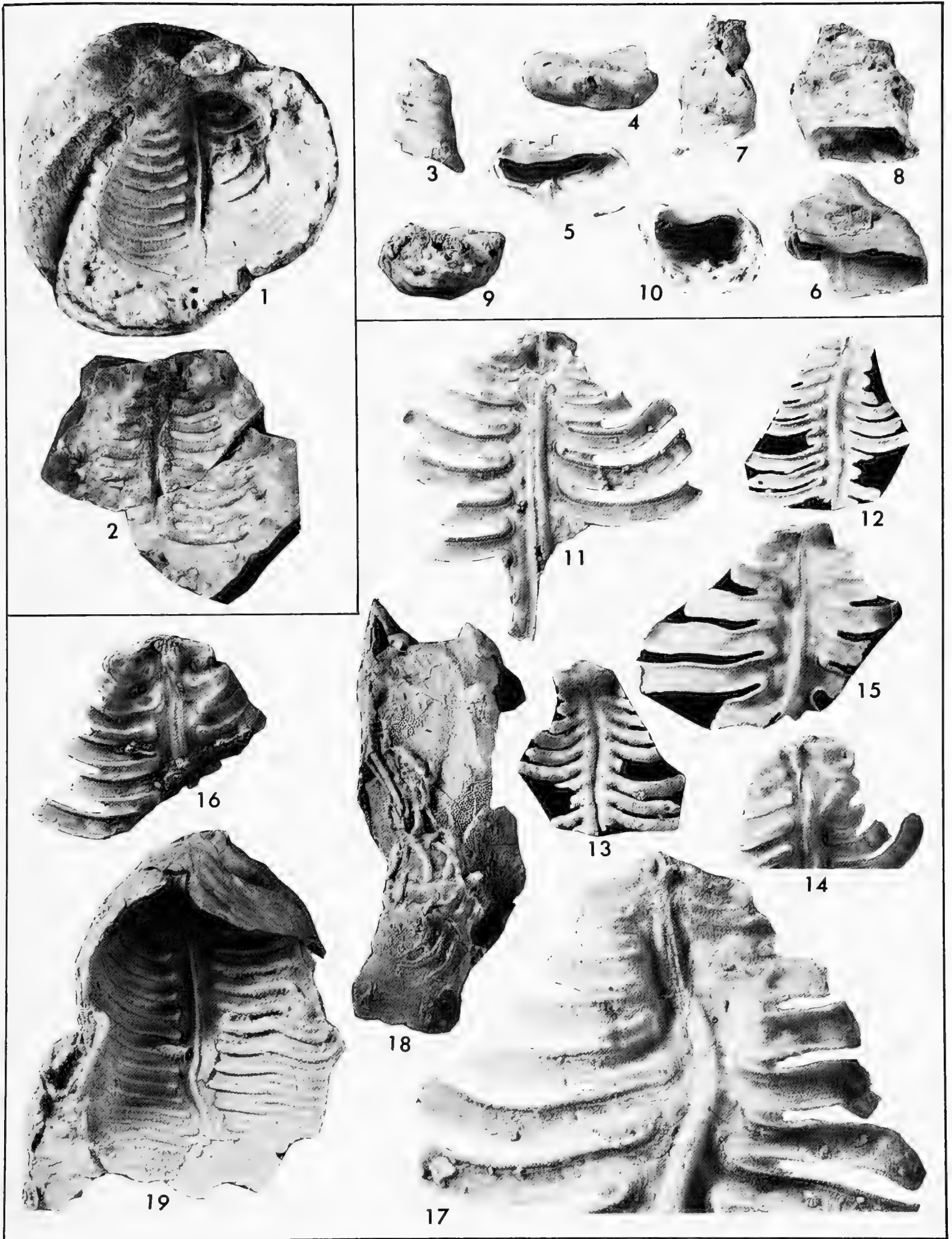
*Eolyttonia parviconica*, new species: 3–6, Side, posterior, anterior, dorsal views of a pedicle valve with long cowl,  $\times$  1, holotype USNM 153626a; 7–10, side, dorsal, posterior, and anterior views of another cowed pedicle valve,  $\times$  1, paratype USNM 153626b [Road Canyon Formation, locality USNM 726d].

*Eolyttonia progressa*, new species: 11, Interior of an incomplete brachial valve, showing cardinal process,  $\times$  2, paratype USNM 150749e (for an additional view, see Plate 161: figure 4); 12, 13, interior and exterior of a more nearly complete brachial valve,  $\times$  1, paratype USNM 150749i; 14, posterior of the preceding specimen,  $\times$  2; 15, interior of another, but younger, brachial valve,  $\times$  2, paratype USNM 150749f; 16, posterior part of another brachial valve, showing cardinal process,  $\times$  2, paratype USNM 150749h [Cherry Canyon Formation (Getaway Member), locality USNM 728 = AMNH 512].

17, Posterior of a large brachial valve, showing bilobed cardinal process,  $\times$  2, paratype USNM 150739c (for additional views, see Plate 159: figure 1) [Word Formation (Appel Ranch Member), locality USNM 715i].

18, 19, Side and dorsal views of a long, narrow pedicle valve with large cowl and solidi to anguliseptate lobes,  $\times$  1, holotype USNM 151311a [Word Formation (Appel Ranch Member), locality USNM 719z].

PLATE 160.—*Eolyttonia*.



## PLATE 161

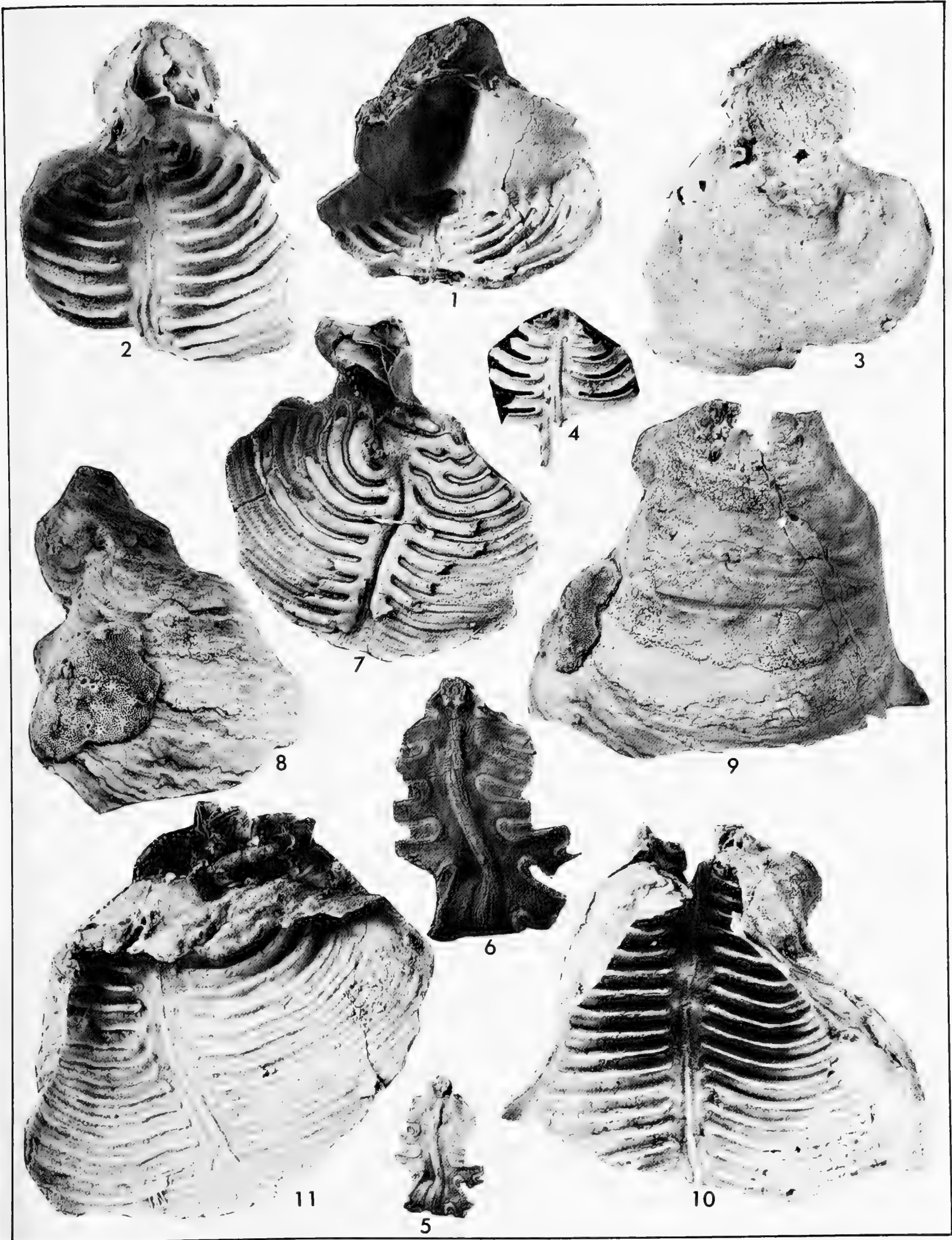
*Eolyttonia*

*Eolyttonia progressa*, new species: 1, Interior of a fragmentary specimen tilted to show the large cowl,  $\times$  1, paratype USNM 151311d [Word Formation (Appel Ranch Member), locality USNM 719z].

2, 3, Interior and exterior views of a pedicle valve with narrow hood,  $\times$  1, paratype USNM 150749d; 4, interior of a fragmentary brachial valve (for enlarged views, see Plate 160: figure 11); 5, 6, interior of another, more complete brachial valve, showing cardinal process,  $\times$  1,  $\times$  2, paratype USNM 150749g; 7, dorsal view of specimen with distorted interior,  $\times$  1, paratype USNM 150746a; 8–10, side, ventral, and interior views of a large pedicle valve with long hood,  $\times$  1, paratype USNM 150749a; 11, interior of another large pedicle valve with large cowl,  $\times$  1, paratype USNM 150749b [Cherry Canyon Formation (Getaway Member), locality USNM 728 = AMNH 512].



PLATE 161.—*Eolyttonia*.





## PLATE 162

*Eolyttonia* and *Choanodus*

*Eolyttonia* species 2: 1, Small pedicle valve attached to one of its fellows,  $\times$  1, paratype USNM 150769a; 2–5, side, posterior, ventral, and dorsal views of a larger specimen,  $\times$  1, paratype USNM 150769b; 6, 7, ventral and dorsal views of a still larger pedicle valve,  $\times$  1, paratype USNM 150769c [Cathedral Mountain Formation, locality USNM 702un].

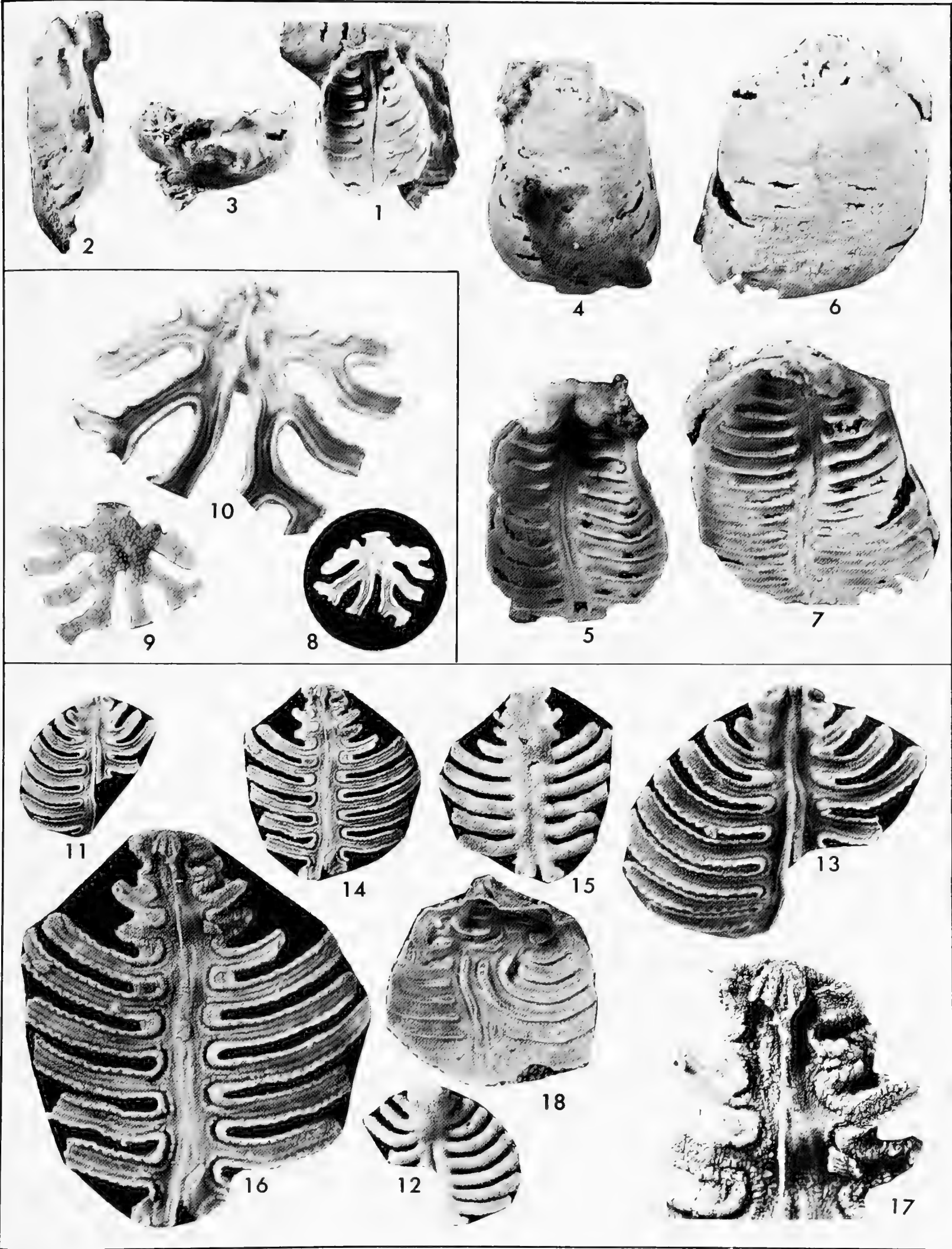
*Choanodus irregularis*, new species: 8, Interior of a brachial valve,  $\times$  1.5, paratype USNM 150826c; 9, exterior of the preceding specimen, showing the granular surface,  $\times$  2; 10, interior of the preceding brachial valve, showing the cardinal process,  $\times$  3 [Cathedral Mountain Formation, locality USNM 702].

*Eolyttonia diabloensis* (Stehli): 11, 12, Interior and exterior views of a brachial valve,  $\times$  1, hypotype USNM 150620a; 13, interior of the preceding specimen, showing the fluted lobes and cardinal process,  $\times$  2 [Bone Spring Formation, locality AMNH 629].

14, 15, Interior and exterior of a nearly complete brachial valve,  $\times$  1, hypotype USNM 153648; 16, interior of the preceding specimen, showing the fluted lobes and cardinal process,  $\times$  2; 17, interior of the posterior of the preceding specimen, showing cardinal process,  $\times$  2 [Bone Spring Formation (base), locality USNM 728e].

18, Interior of a small pedicle valve, showing irregular development of the loops at the posterior,  $\times$  1, hypotype USNM 153649 [Bone Spring Formation, locality USNM 728f].

PLATE 162.—*Eolyttonia* and *Choanodus*.



## PLATE 163

*Petasmaia*

*Petasmaia expansa* Cooper and Grant: 1, 2, Side and dorsal views of a large specimen attached to a richthofeniid,  $\times 1$ , holotype USNM 151343; 3, interior of the pedicle valve of the preceding specimen with mostly angulisepta, showing the striated and overhanging lobes,  $\times 1$ ; 4, interior of the brachial valve of the preceding specimen,  $\times 1$ ; 5, same brachial valve as preceding enlarged to show bilobed cardinal process,  $\times 2$ ; 6, 7, exterior and interior of another brachial valve,  $\times 1$ , hypotype USNM 155128b [Cathedral Mountain Formation, locality USNM 702un].

8, Interior of a pedicle valve attached to another *Petasmaia*, showing "dental plates" and median ridge,  $\times 2$ , hypotype USNM 153600 (for brachial valve of this specimen, see Plate 164: figure 15) [Cathedral Mountain Formation, locality AMNH 500H = USNM 702].

PLATE 163.—*Petasmaia*.



## PLATE 164

*Petasmaia*

*Petasmaia expansa* Cooper and Grant: 1, 2, Exterior and interior of a young specimen, showing anterior plane area with lobes and latilobate to angustilobate lobes not yet developed,  $\times 1$ , paratype USNM 151341e; 3, interior of an immature brachial valve with poorly developed cardinal process,  $\times 1$ , hypotype USNM 155129b; 4, another young brachial valve interior,  $\times 1$ , hypotype USNM 155129a; 5, posterior of a pedicle valve, showing dental plates and solidi to angulisepta dental plates,  $\times 2$ , hypotype USNM 151341-1 [Cathedral Mountain Formation, locality USNM 702b].

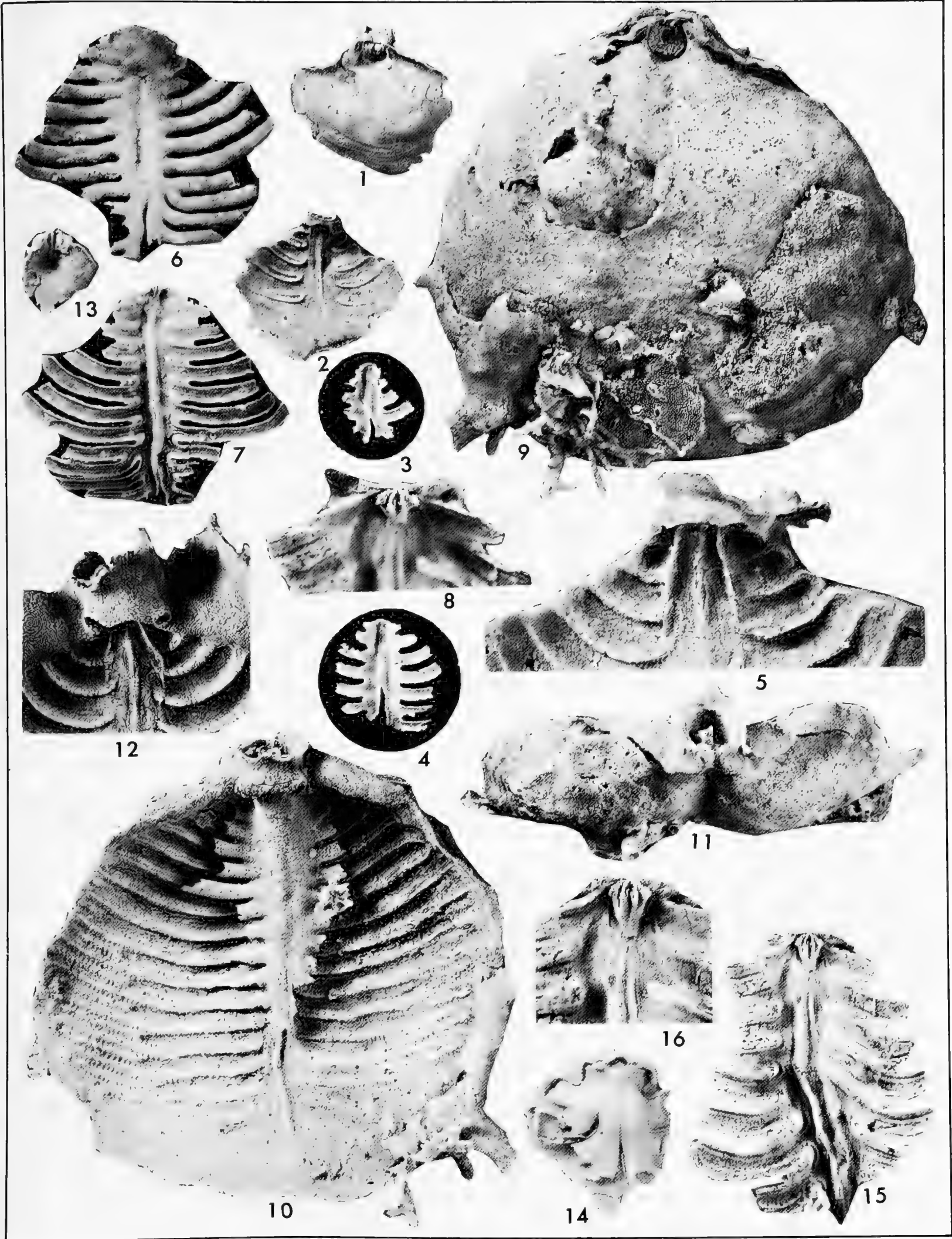
6, 7, Exterior and interior of a brachial valve,  $\times 1$ , hypotype USNM 155128c; 8, posterior of the preceding specimen, tilted to show cardinal process  $\times 2$  (for an additional view of this specimen, see Plate 169: figure 15); 9, 10, dorsal view of an unusually large specimen preserving the axial part of the brachial valve and having angustilobate septa posteriorly and solidilobate to anguliseptate anteriorly,  $\times 1$ , hypotype USNM 153601a; 11, posterior of another pedicle valve, showing attachment on crinoid stem,  $\times 1$ , hypotype USNM 153601b; 12, posterior of interior of same valve as preceding, showing "dental plates" and articulating area for brachial valve,  $\times 1$  [Cathedral Mountain Formation, locality USNM 702un].

13, Exterior of an immature pedicle valve,  $\times 1$ , hypotype USNM 153599b; 14, dorsal view of the preceding specimen, showing the brachial valve in place,  $\times 2$  [Cathedral Mountain Formation, locality USNM 726x].

15, Interior of the brachial valve, showing cardinal process and median ridge,  $\times 2$ , hypotype USNM 153600 (for pedicle valve of this specimen, see Plate 163: figure 8); 16, posterior of the preceding specimen, showing the lobate cardinal process with bifurcated shaft,  $\times 3$  [Cathedral Mountain Formation, locality AMNH 500 H = USNM 702].



PLATE 164.—*Petasmaia*.



## PLATE 165

*Petasmaia*

*Petasmaia expansa*, Cooper and Grant: 1, 2, Exterior and interior of a very young pedicle valve with incomplete vallum,  $\times$  1, paratype USNM 151341g; 3, interior of the same specimen, showing poorly developed lobes,  $\times$  2; 4, 5, interior and exterior of a specimen larger than the preceding and showing well-developed angustilobate lobes,  $\times$  1, paratype USNM 151341f; 6, interior of the preceding specimen, showing "dental plates,"  $\times$  2; 7, 8, exterior and interior of another young specimen, showing folded attachment and latilobate lobes,  $\times$  1, paratype USNM 151341d; 9, interior of an immature brachial valve,  $\times$  2, hypotype USNM 155129c; 10, 11, interior and exterior of a young adult, showing well-defined, wide angustilobate lobes, dental plates, and attachment to crinoid stem,  $\times$  1, hypotype USNM 155129d; 12, interior of the preceding specimen, showing "dental plates" and lobes,  $\times$  2; 22, 23, interior and exterior views of an unusually large and flat pervallate pedicle valve,  $\times$  1, paratype USNM 151341a; 24, interior of another pedicle valve, showing narrow delthyrial cavity with median ridge, "dental plates," and angustilobate to anguliseptate lobes,  $\times$  1, hypotype USNM 155128b [Cathedral Mountain Formation, locality USNM 702b].

13, Young specimen preserving both valves and attached to a crinoid stem,  $\times$  1, paratype USNM 153598 [Cathedral Mountain Formation, locality USNM 703b].

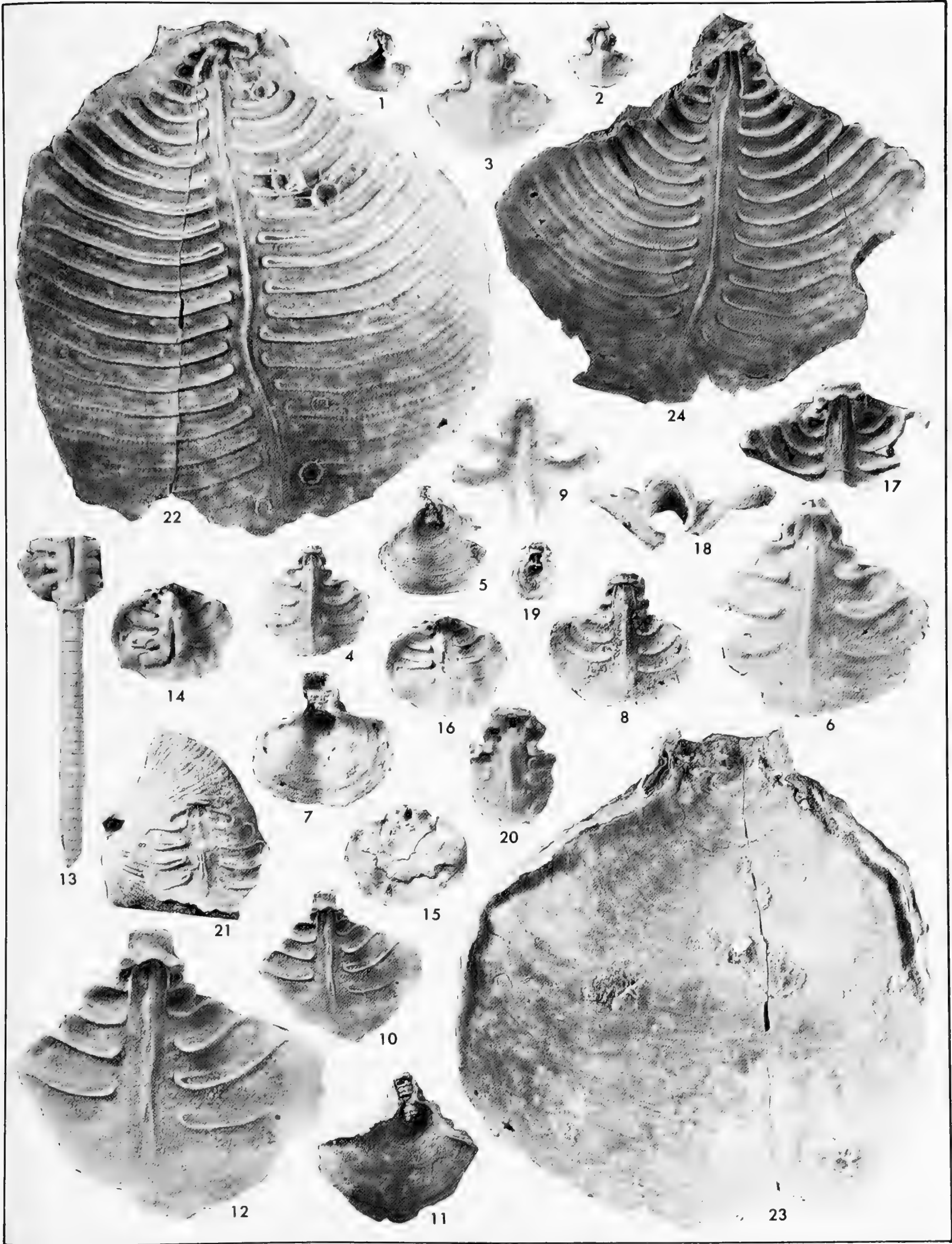
14, 15, Dorsal and exterior views of a young specimen with both valves,  $\times$  1, paratype USNM 151339; 16, interior of the pedicle valve of the preceding specimen with brachial valve removed,  $\times$  1 [Cathedral Mountain Formation, locality USNM 702].

17, 18, Dorsal and posterior views of an incomplete pedicle valve, showing "dental plates" and attachment tube,  $\times$  1, paratype USNM 151345 [Road Canyon Formation, locality USNM 720d].

19, Exterior view of an immature specimen,  $\times$  1, paratype USNM 153599a; 20, interior of preceding specimen, showing incipient latilobate lobes,  $\times$  2 [Cathedral Mountain Formation, locality USNM 726x].

21, Interior of a pedicle valve attached to *Lepidospirifer*, showing angustilobate lobes, an unusual occurrence for the genus,  $\times$  1, paratype USNM 151343f [Cathedral Mountain Formation, locality USNM 702un].

PLATE 165.—*Petasmaia*.



## PLATE 166

*Loxophragmus*

*Loxophragmus ellipticus*, new species: 1, Interior of an average pedicle valve,  $\times$  1, paratype USNM 150682a; 2, preceding terminivallate specimen, showing details of the lateral lobes,  $\times$  2; 28, 29, exterior,  $\times$  1, and interior,  $\times$  2, of an immature brachial valve, paratype USNM 150682b; 33, exterior of a brachial valve,  $\times$  1, paratype USNM 150682c [Cathedral Mountain Formation, locality USNM 702ent].

3, Dorsal view of an adult with both valves in place,  $\times$  1, paratype USNM 150681c; 4, the preceding,  $\times$  2; 10–12, ventral, posterior, and side views of another pedicle valve,  $\times$  1, paratype USNM 150683g; 13, interior of the preceding, showing the striated angulisepta,  $\times$  2; 16–18, posterior, ventral, anterior views of a large pedicle valve,  $\times$  1, paratype USNM 150683b; 19, the preceding enlarged, showing angustilobate septa as well as angulisepta,  $\times$  2; 20, exterior of a nearly complete brachial valve,  $\times$  1, paratype USNM 150681d; 21, 22, interior and exterior of the preceding,  $\times$  2 [Cathedral Mountain Formation, locality USNM 702b].

5–8, Ventral, side, posterior, and dorsal views of a complete specimen,  $\times$  1, holotype USNM 150685; 9, the holotype,  $\times$  2 [Cathedral Mountain Formation, locality USNM 702 (low)].

23, 24, Interior and exterior of a complete brachial valve,  $\times$  2, paratype USNM 153612a; 25, exterior of another, larger brachial valve,  $\times$  1, paratype USNM 153612b; 26, 27, interior and exterior of the preceding specimen,  $\times$  2 [Cathedral Mountain Formation, locality USNM 703bs].

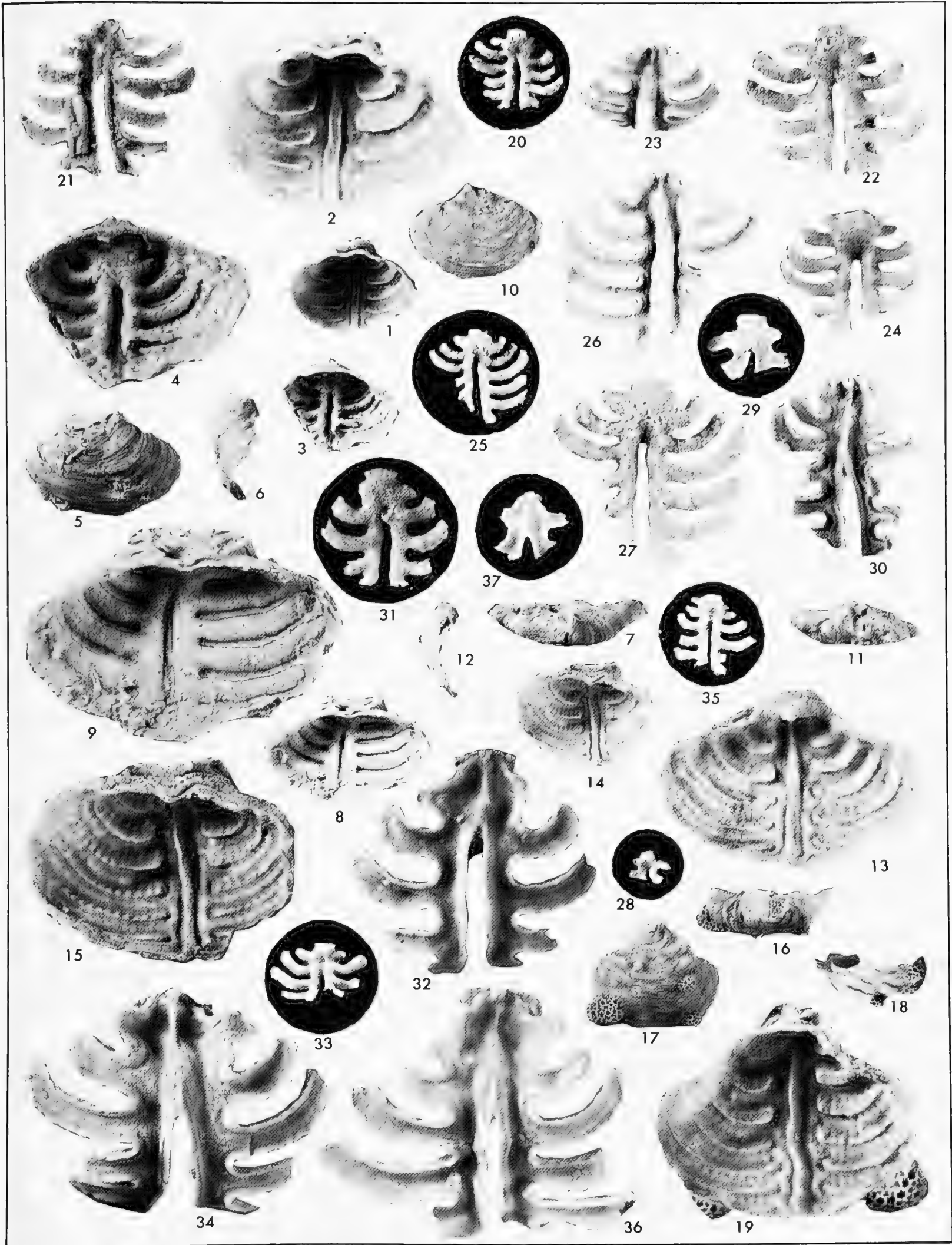
30, Interior of a brachial valve, showing the cardinal process,  $\times$  2, paratype USNM 153613 [Cathedral Mountain Formation, locality USNM 702].

31, Exterior of a small brachial valve,  $\times$  2, paratype USNM 153614d; 32, interior of preceding specimen, showing cardinal process,  $\times$  4; 34, interior of another brachial valve,  $\times$  4, paratype USNM 153614a; 35, exterior of an elongated brachial valve,  $\times$  1, paratype USNM 153614b; 36, interior of the preceding specimen, showing the cardinal process,  $\times$  4; 37, interior of another immature brachial valve,  $\times$  2, paratype USNM 153614c [Cathedral Mountain Formation, locality USNM 726x].

14, 15, Interior of a terminivallate pedicle valve,  $\times$  1,  $\times$  2, paratype USNM 150686a [Cathedral Mountain Formation, locality USNM 702un].



PLATE 166.—*Loxophragmus*.





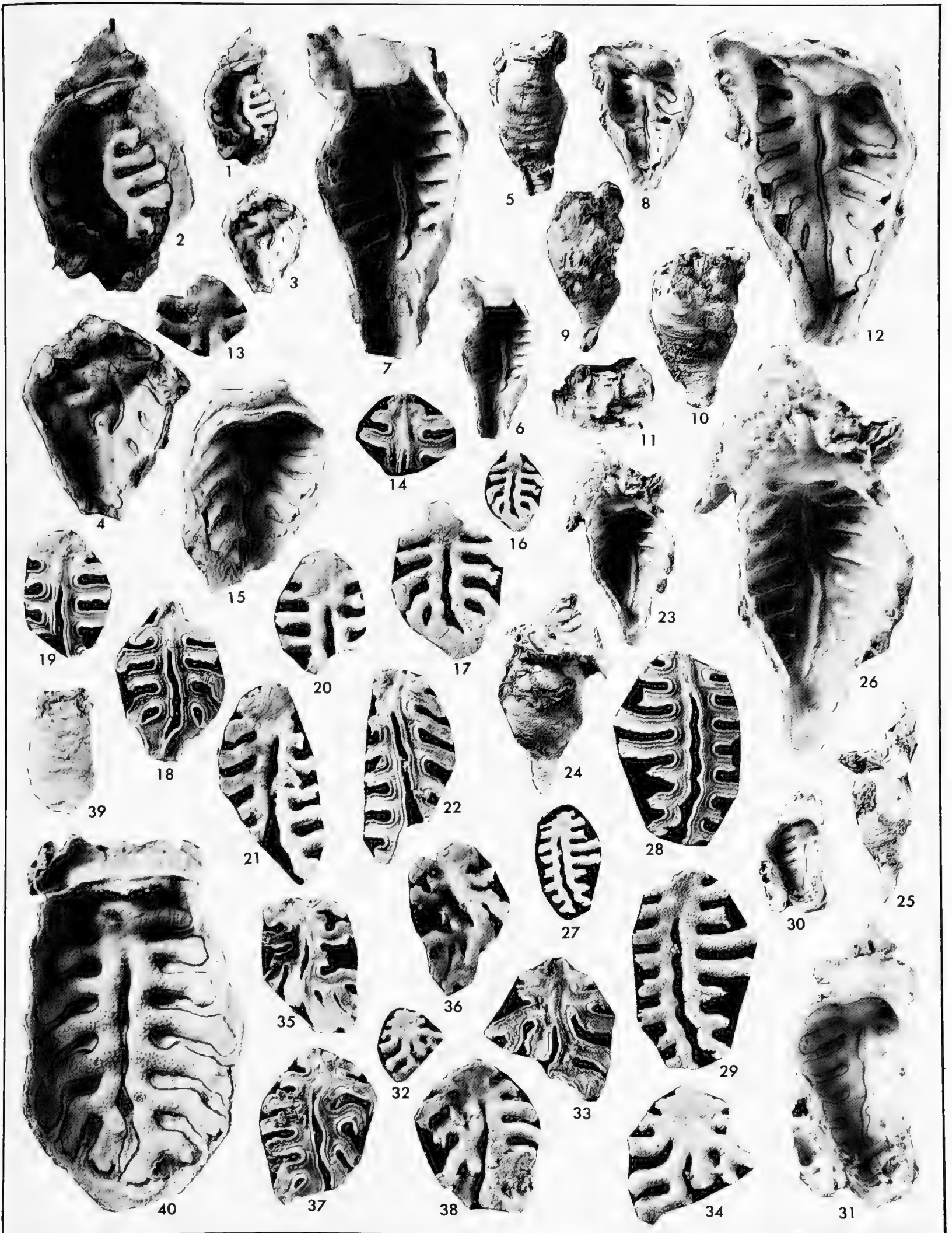
## PLATE 167

*Collemataria*

*Collemataria batilliformis*, new species: 1, 2, Dorsal view,  $\times 1$ ,  $\times 2$ , of a complete specimen, paratype USNM 153602h; 3, 4, dorsal view of another specimen preserving both valves and showing many of the lobes of the brachial valve fused,  $\times 1$ ,  $\times 2$ , paratype USNM 153602d; 27, exterior of an elongated brachial valve,  $\times 1$ , paratype USNM 153602b; 28, 29, interior and exterior of the preceding specimen,  $\times 2$ ; 32, exterior of a brachial valve with irregular and fused lobes,  $\times 1$ , paratype USNM 153602e; 33, 34, interior and exterior of the preceding specimen,  $\times 2$  [Road Canyon Formation, locality USNM 721j].

5, 6, Ventral and interior views of an elongate, somewhat siphonate, pedicle valve,  $\times 1$ , paratype USNM 153603x; 7, interior of the preceding specimen, showing angulisepta,  $\times 2$ ; 8–11, dorsal, side, ventral, and posterior views of a complete and siphonate specimen,  $\times 1$ , holotype USNM 153603s; 12, dorsal view of the preceding specimen,  $\times 2$ ; 13, 14, exterior and interior views of an immature brachial valve,  $\times 2$ , paratype USNM 153603b; 15, dorsal view of a complete specimen,  $\times 2$ , paratype USNM 153603h; 16, exterior of a brachial valve,  $\times 1$ , paratype USNM 153603o; 17, 18, exterior and interior views of the preceding specimen, showing coalesced lobes,  $\times 2$ ; 19, 20, interior and exterior of another brachial valve,  $\times 2$ , paratype USNM 153603f; 21, 22, exterior and interior of an elongated brachial valve,  $\times 2$ , paratype USNM 153603m; 23–25, dorsal, ventral, and side views of a siphonate pedicle; 26, dorsal view of the preceding specimen,  $\times 2$ , valve,  $\times 1$ , paratype USNM 153603z; 30, 31, dorsal view of a small pedicle valve,  $\times 1$ ,  $\times 2$ , paratype USNM 153603v; 35, 36, interior and exterior of a misshapen brachial valve,  $\times 2$ , paratype USNM 153603g; 37, 38, interior and exterior of another distorted brachial valve,  $\times 2$ , paratype USNM 153603c; 39, ventral view of a fairly symmetrical individual,  $\times 1$ , paratype USNM 153603n; 40, dorsal view of the preceding specimen,  $\times 3$  [Road Canyon Formation, locality USNM 726d].

PLATE 167.—*Collemataria*.



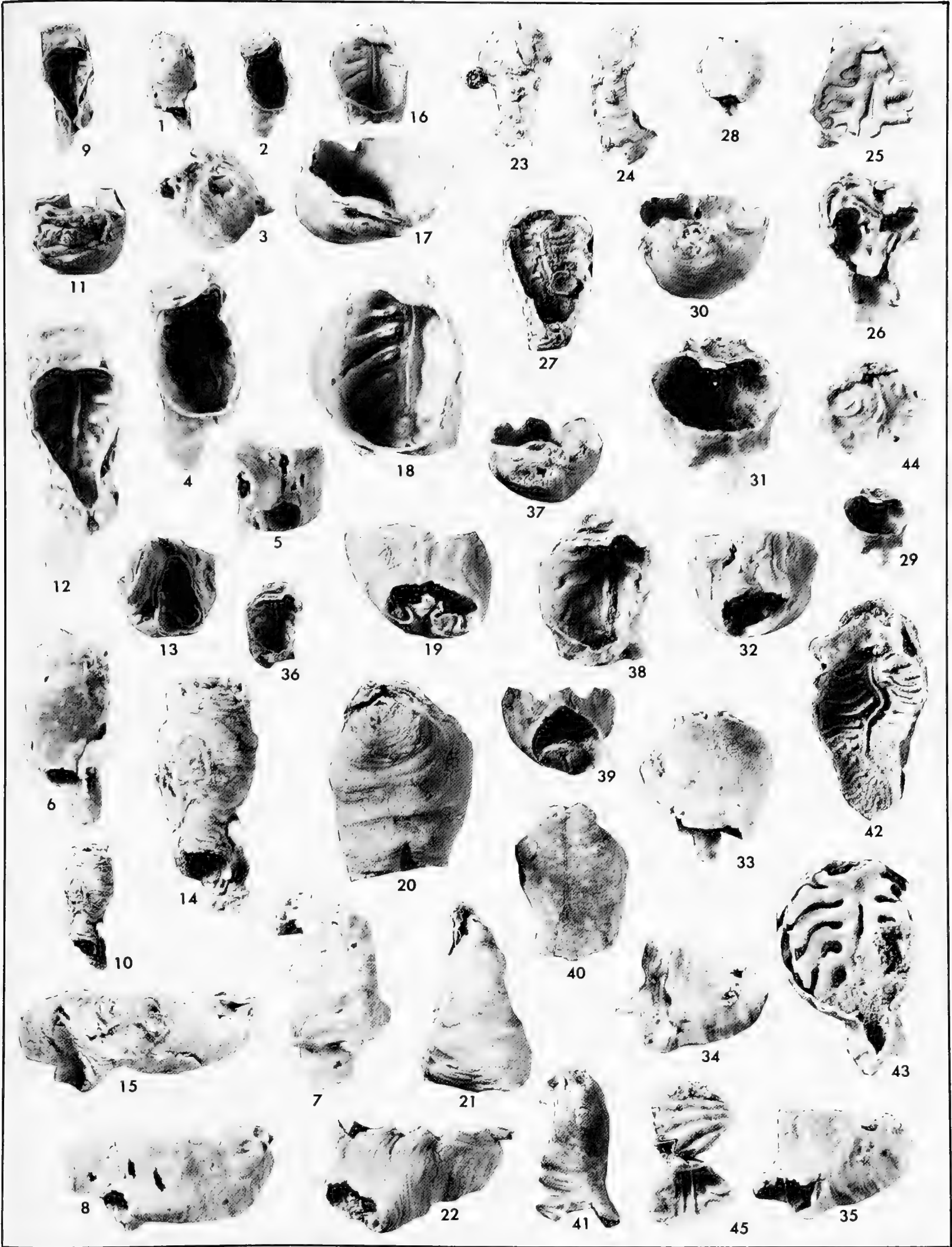
## PLATE 168

*Collemataria*

*Collemataria batilliformis*, new species: 1, 2, Ventral and dorsal views of a small siphonate specimen,  $\times 1$ , paratype USNM 153602i; 3-8, posterior, dorsal, anterior, ventral, and two side views of the preceding specimen,  $\times 2$ ; 9, 10, dorsal and ventral views of a small, slender, siphonate specimen,  $\times 1$ , paratype USNM 153602g; 11-15, posterior, dorsal, anterior, ventral, and side views of the preceding specimen,  $\times 2$ ; 16, dorsal view of a small but broad specimen,  $\times 1$ , paratype USNM 153602f; 17-22, posterior, dorsal, anterior, ventral, side, and partial side views of the preceding specimen, showing angustilobate lobes, the anterior siphona  $\times 2$ ; 26, ventral view of a small, misshapen, but strongly siphonate individual,  $\times 2$ , paratype USNM 153602c; 28, 29, ventral and dorsal views of a small, siphonate individual,  $\times 1$ , paratype USNM 150815-1; 30-35, posterior, dorsal, anterior, ventral, side, and tilted side (to show siphon) views of the preceding specimen,  $\times 2$ ; 36, dorsal view of a small siphonate pedicle valve,  $\times 1$ , paratype USNM 150815c; 37-41, posterior, dorsal, anterior, ventral, and side views of the preceding specimen,  $\times 2$ ; 42, interior of a large individual with solidisepta,  $\times 1$ , paratype USNM 153602j; 43, a siphonate specimen with brachial valve in place, seen in dorsal view,  $\times 2$ , paratype USNM 153602a [Road Canyon Formation, locality USNM 721j].

23, 24, Ventral and side views of an elongated, siphonate specimen,  $\times 1$ , paratype USNM 153603t; 25, dorsal view of an immature specimen, preserving both valves,  $\times 2$ , paratype USNM 153603u; 27, dorsal view of a large siphonate specimen,  $\times 1$ , paratype USNM 153603p; 44, immature specimen, circular in form,  $\times 2$ , paratype USNM 153603y; 45, immature specimen attached to *Hustedia*,  $\times 2$ , paratype USNM 153603e [Road Canyon Formation, locality USNM 726d].

PLATE 168.—*Collemataria*.



## PLATE 169

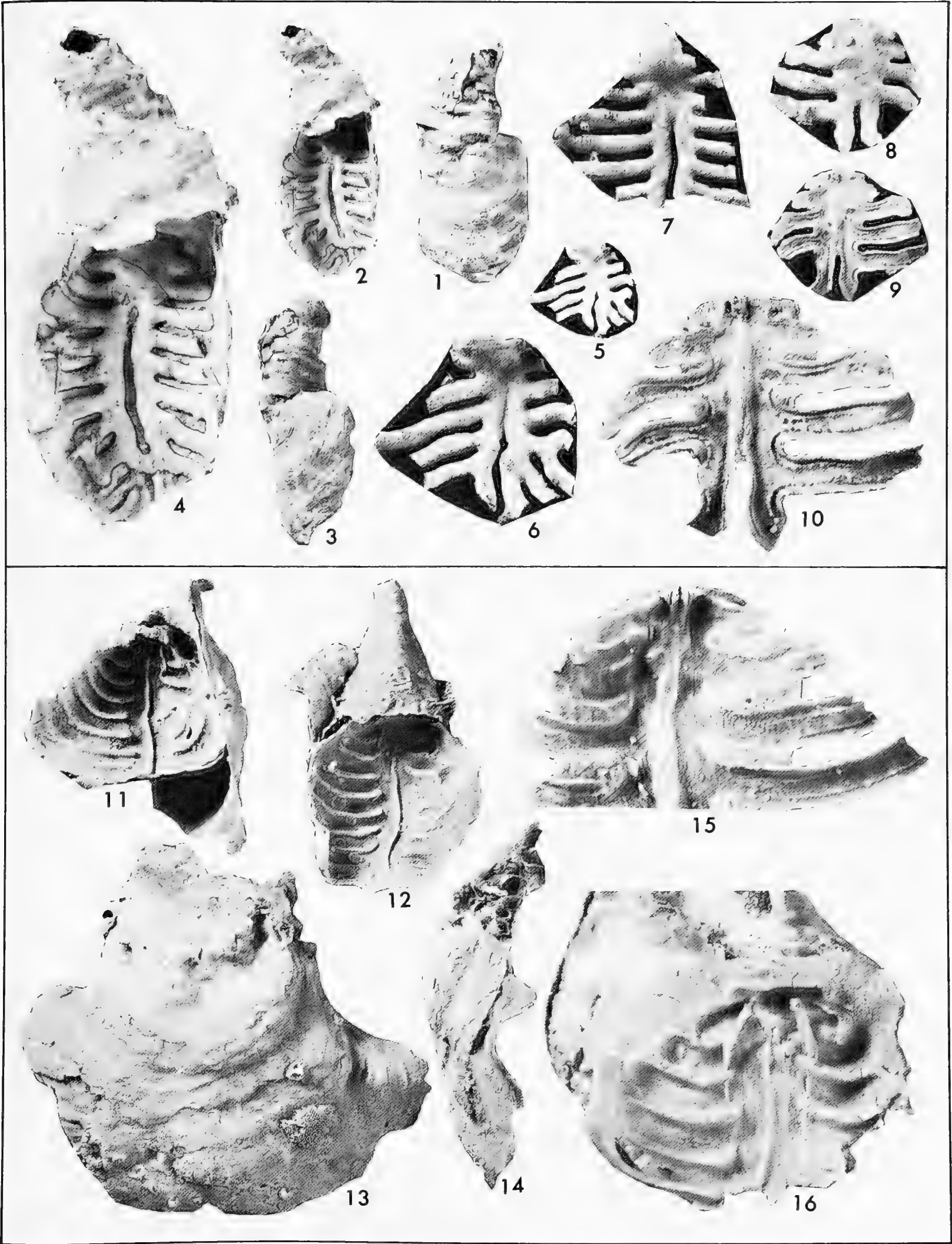
*Collemataria* and *Petasmaia*

*Collemataria batilliformis*, new species: 1-3, Exterior, dorsal, and side views of a large individual attached to a richthofeniid,  $\times 1$ , paratype USNM 153603w; 4, dorsal view of the same specimen as preceding,  $\times 2$ ; 5, 6, exterior of a brachial valve, showing irregular development of lobes,  $\times 1$ ,  $\times 2$ , paratype USNM 153603-l; 7, exterior of another brachial valve, showing median cleft,  $\times 2$ , paratype USNM 153603q; 8, 9, exterior and interior of a small brachial valve,  $\times 2$ , paratype USNM 153603i; 10, interior of preceding specimen, showing cardinal process and beaded ridges on inside of lobes,  $\times 4$  [Road Canyon Formation, locality USNM 726d].

*Petasmaia expansa*, new species: 11, Specimen attached inside the concave exterior of *Rugatia*,  $\times 1$ , hypotype USNM 155128d; 12, another pedicle valve attached inside an *Hercosia* valve,  $\times 1$ , hypotype USNM 155128e; 13, 14, exterior and side views of a misshapen pedicle valve,  $\times 1$ , hypotype USNM 155128h; 15, posterior of a brachial valve, showing cardinal process,  $\times 3$ , hypotype USNM 155128c (for other views of this specimen, see Plate 164: figures 6-8); 16, interior of a pedicle valve attached to *Neospirifer*, showing strong "dental plates" and median ridge,  $\times 2$ , hypotype USNM 155128g [Cathedral Mountain Formation, locality USNM 702un].



PLATE 169.—*Collemataria* and *Petasmaia*.

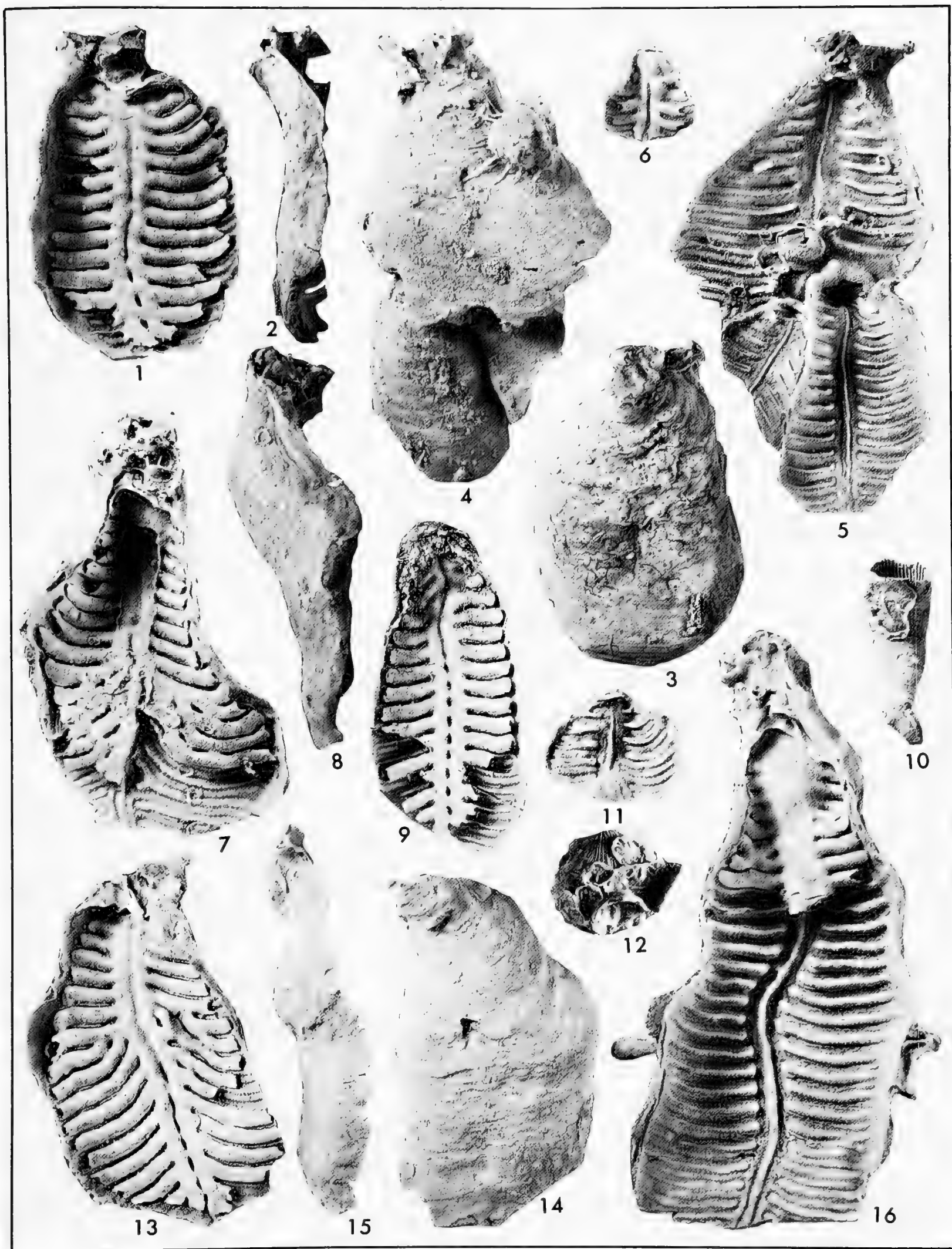


## PLATE 170

*Collemataria*

*Collemataria elongata*, new species: 1-3, Dorsal, side, and ventral views of a medium-sized elliptical specimen,  $\times 1$ , paratype USNM 153631a; 4, 5, ventral and dorsal views of a small cluster of pedicle valves,  $\times 1$ , paratype USNM 153628f; 6, dorsal view of an immature individual,  $\times 1$ , paratype USNM 150820e (for exterior view, see Plate 173: figure 5); 7, 8, dorsal and side views of an anteriorly expanding specimen, with irregular lobation,  $\times 1$ , paratype USNM 153631b; 9, dorsal view of a small adult having an unusually large number of unfilled pits in the axis,  $\times 1$ , paratype USNM 150820f (the generic character of *Gubleria*); 10, dorsal view of a juvenile attached to a cup coral,  $\times 1$ , paratype USNM 153628g; 11, dorsal view of a flat, immature pedicle valve, with angustilobate lobes,  $\times 1$ , paratype USNM 153628h; 12, a brachial valve of *Meekella* with immature *Collemataria* attached,  $\times 1$ , paratype USNM 153628i; 13, 14, dorsal and ventral views of a complete specimen, showing irregular development of the lobes of the brachial valve,  $\times 1$ , paratype USNM 150820g; 15, side view of an adult,  $\times 1$ , paratype USNM 153630 (for the dorsal view, see Plate 172: figure 16); 16, dorsal view of an unusually large and elongated specimen, preserving part of the brachial valve, and having some angustilobate lobes and some solidiseptate lobes,  $\times 1$ , paratype USNM 150821a [Word Formation (Willis Ranch Member), locality USNM 706e].

PLATE 170.—*Collemataria*.



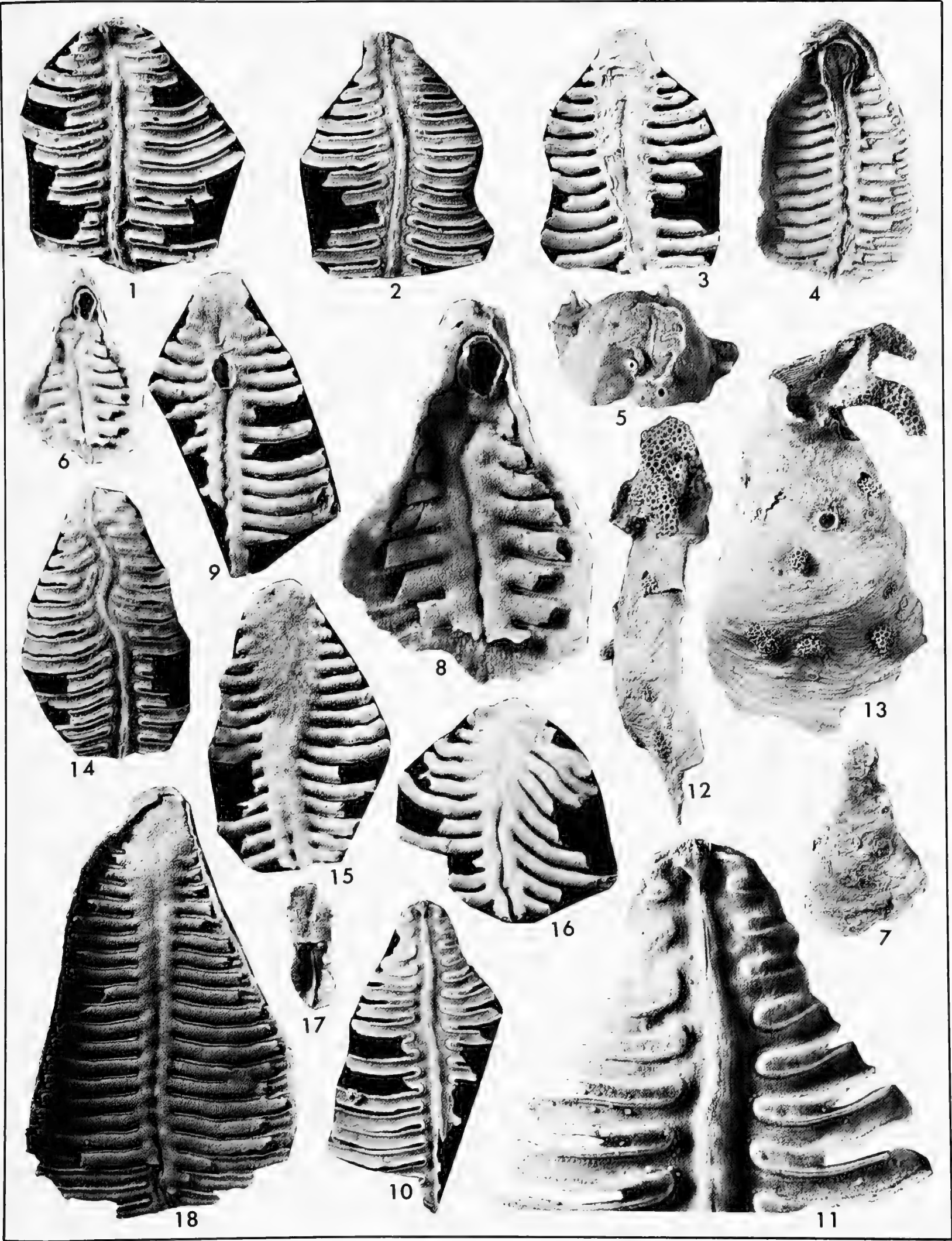
## PLATE 171

*Collemataria*

*Collemataria elongata*, new species: 1, Interior of a large brachial valve,  $\times$  1, paratype USNM 153634a; 2, 3, interior and exterior of another brachial valve,  $\times$  1, paratype USNM 153634b; 4, dorsal view of a small individual, showing exploded blister at posterior of brachial valve axis,  $\times$  1, paratype USNM 153634c; 5, immature pedicle valve cemented to the pedicle valve of *Paucispinifera* and showing angustilobate ridges,  $\times$  1, paratype USNM 153643d; 6, 7, dorsal and exterior views of a small acuminate individual,  $\times$  1, paratype USNM 153634e; 8, dorsal view of the preceding, showing exploded blister at posterior of the brachial valve,  $\times$  2; 9, 10, exterior and interior views of a large brachial valve,  $\times$  1, paratype USNM 153634f; 11, posterior part of the preceding to show the cardinal process and filled-in spaces between lobes,  $\times$  3; 12, 13, side and exterior views of a pedicle valve, showing cast of a pelecypod in the cicatrix,  $\times$  1, paratype USNM 150821e; 14, 15, interior and exterior views of a brachial valve,  $\times$  1, paratype USNM 153634g; 16, exterior of another brachial valve, showing irregular development and branching of lateral lobes,  $\times$  1, paratype USNM 150820n; 17, interior of a small, narrow pedicle valve with long granulose posterior flap,  $\times$  1, paratype USNM 153634h; 18, dorsal view of a remarkably symmetrical individual,  $\times$  1, paratype USNM 150819b [Word Formation (Willis Ranch Member), locality USNM 706e].



PLATE 171.—*Collemataria*.



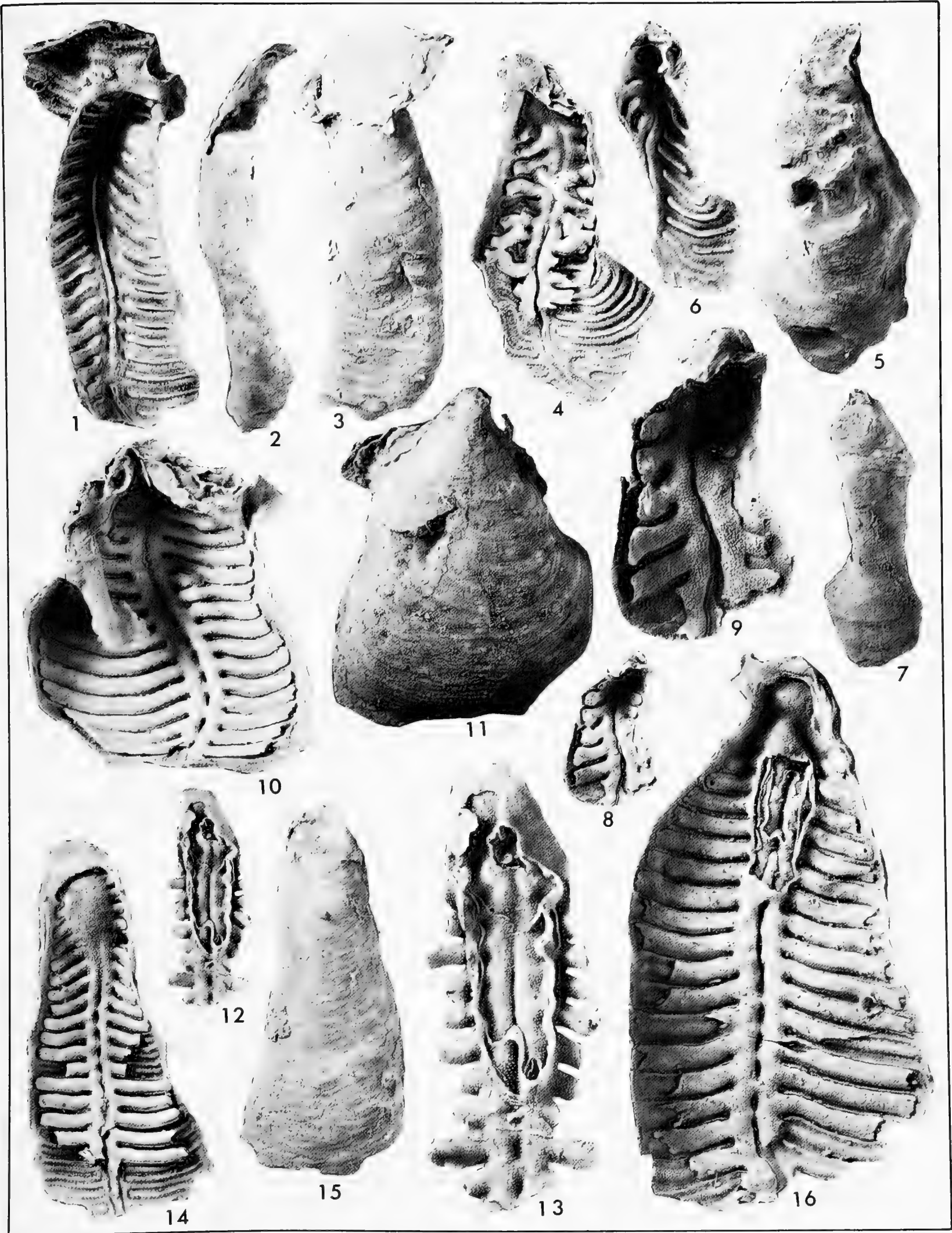


## PLATE 172

*Collemataria*

*Collemataria elongata*, new species: 1-3, Interior, side, and exterior views of an unusually elongated pedicle valve with a majority of angustilobate ridges,  $\times 1$ , paratype USNM 153628b; 4, 5, dorsal and exterior views of specimen preserving both valves but with the lobes of the brachial valve distorted,  $\times 1$ , paratype USNM 150817a; 6, 7, dorsal and ventral views of a slender, distorted pedicle valve,  $\times 1$ , paratype USNM 153638c; 8, 9, dorsal view of an immature specimen with both valves,  $\times 1$ ,  $\times 2$ , paratype USNM 153628d (for exterior, see Plate 173: figure 21); 10, 11, dorsal and ventral views of a complete specimen, showing part of the posterior flap growing over an elongate body that had impinged against the shell,  $\times 1$ , paratype USNM 150820c; 12, 13, posterior part of a brachial valve in exterior view, showing the blister-like structure,  $\times 1$ ,  $\times 2$ , paratype USNM 153628e; 14, 15, dorsal and ventral views of a complete, elongated, and narrow individual, not with blister at rear but with open lacunae in the medial axial part,  $\times 1$ , paratype USNM 150817b; 16, dorsal view of a complete specimen with broken blister at posterior of pedicle valve,  $\times 1.5$ , paratype USNM 153630 (for side view, see Plate 170: figure 15) [Word Formation (Willis Ranch Member), locality USNM 706e].

PLATE 172.—*Collemataria*.

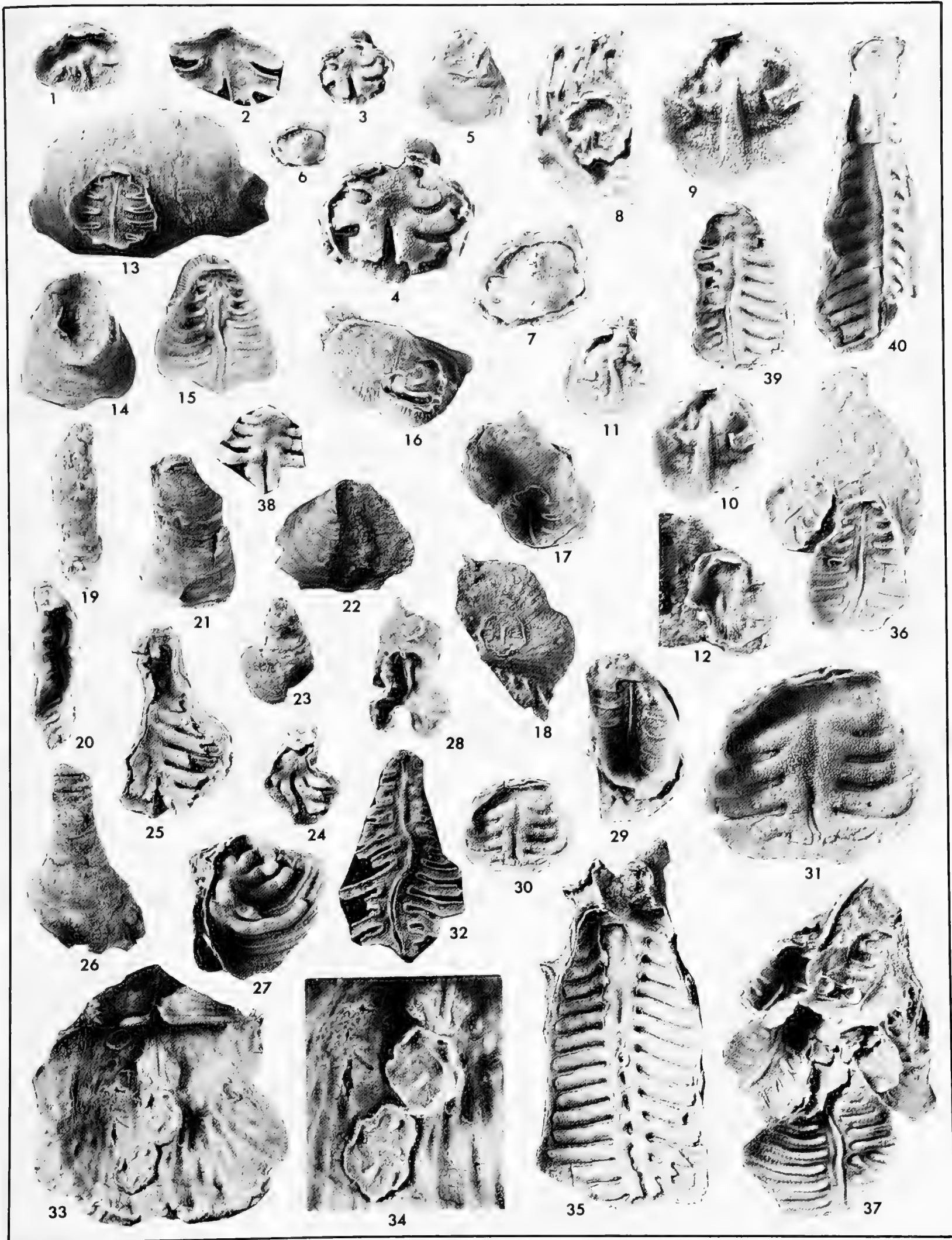


## PLATE 173

*Collemataria*

*Collemataria elongata*, new species: 1, Interior of an immature pedicle valve, paratype with only one angustilobate lobe,  $\times 2$ , USNM 153632a; 2, interior of an immature brachial valve,  $\times 2$ , paratype USNM 153632b; 3, 4, dorsal view of an immature complete specimen,  $\times 1$ ,  $\times 2$ , paratype USNM 150820d; 5, exterior of an immature specimen,  $\times 1$ , paratype USNM 150820e (for dorsal view of this specimen, see Plate 170: figure 6); 6, 7, dorsal view of an immature specimen in which the lobes are just beginning to form,  $\times 1$ ,  $\times 2$ , paratype USNM 153632d; 8, dorsal view of an immature pedicle valve just beginning to develop lobation,  $\times 4$ , paratype USNM 153632c; 9, 10, interior of an immature pedicle valve, showing thick median ridge and incipient latilobate lobation,  $\times 4$ ,  $\times 3$ , paratype USNM 153632e; 11, another immature pedicle valve interior,  $\times 2$ , paratype USNM 153632f; 12, another immature pedicle valve interior,  $\times 3$ , paratype USNM 153632g; 13, dorsal view of a youthful pedicle valve with incipiently angustilobate lobes attached to another *Collemataria*,  $\times 1$ , paratype USNM 153628j; 14, 15, ventral and dorsal views of a small pedicle valve attached to a small *Derbyia*,  $\times 1$ , paratype USNM 153628k; 16, an immature and distorted pedicle valve attached to the brachial valve of *Paucispinifera*  $\times 1$ , paratype USNM 153628l; 17, another immature pedicle valve with latilobate lobes attached to the brachial valve of *Paucispinifera*,  $\times 1$ , paratype USNM 153628m; 18, a small pedicle valve with beginning of lobation attached to the pedicle valve of *Paucispinifera*,  $\times 1$ , paratype USNM 153628n; 19, 20, ventral and dorsal views of a very narrow and youthful pedicle valve,  $\times 1$ , paratype USNM 153628o; 21, exterior of an immature specimen,  $\times 1$ , paratype USNM 153628d (for the dorsal view, see Plate 172: figures 8, 9); 22, exterior of a youthful pedicle valve, showing a large cicatrix of attachment,  $\times 1$ , paratype USNM 153628p; 23, 24, exterior and dorsal views of a small, distorted specimen with brachial valve in place,  $\times 1$ , paratype USNM 153628q; 25, 26, dorsal and exterior views of a youthful specimen with one side aborted,  $\times 1$ , paratype USNM 150820h; 27, dorsal view of another greatly distorted specimen,  $\times 1$ , paratype USNM 150820i; 28, small, distorted, and lobate pedicle valve attached to *Echinauris*,  $\times 1$ , paratype USNM 153628r; 29, pedicle valve nestled in the trough of a dorsal valve of *Paucispinifera* and having latilobate lobes on the observer's right and lobes tending toward angustilobate on the left,  $\times 1$ , paratype USNM 153628s; 30, 31, dorsal view of a symmetrical, granulose individual,  $\times 1$ ,  $\times 2$ , paratype USNM 153628t; 32, interior of a brachial valve,  $\times 1$ , paratype USNM 153628u; 33, interior of a pedicle valve of *Echinosteges* with two immature *Collemataria elongata* attached,  $\times 1$ , paratype USNM 153633; 34, enlargement of the preceding specimens, which are in a pervivallate condition,  $\times 2$ ; 35, dorsal view of an adult, showing holes in the axis in process of being closed,  $\times 1$ , paratype USNM 150820j; 36, cluster of youthful valves attached to a larger *Collemataria*,  $\times 1$ , paratype USNM 153628v (note different development of lobes); 37, dorsal view of a matted cluster of youthful individuals,  $\times 1$ , paratype USNM 150820k; 38, exterior of a small brachial valve,  $\times 1$ , paratype USNM 153628w; 39, dorsal view of a small adult,  $\times 1$ , paratype USNM 150820l; 40, dorsal view of an extremely slender individual,  $\times 1$ , paratype USNM 150820m [Word Formation (Willis Ranch Member), locality USNM 706e].

PLATE 173.—*Collemataria*.



## PLATE 174

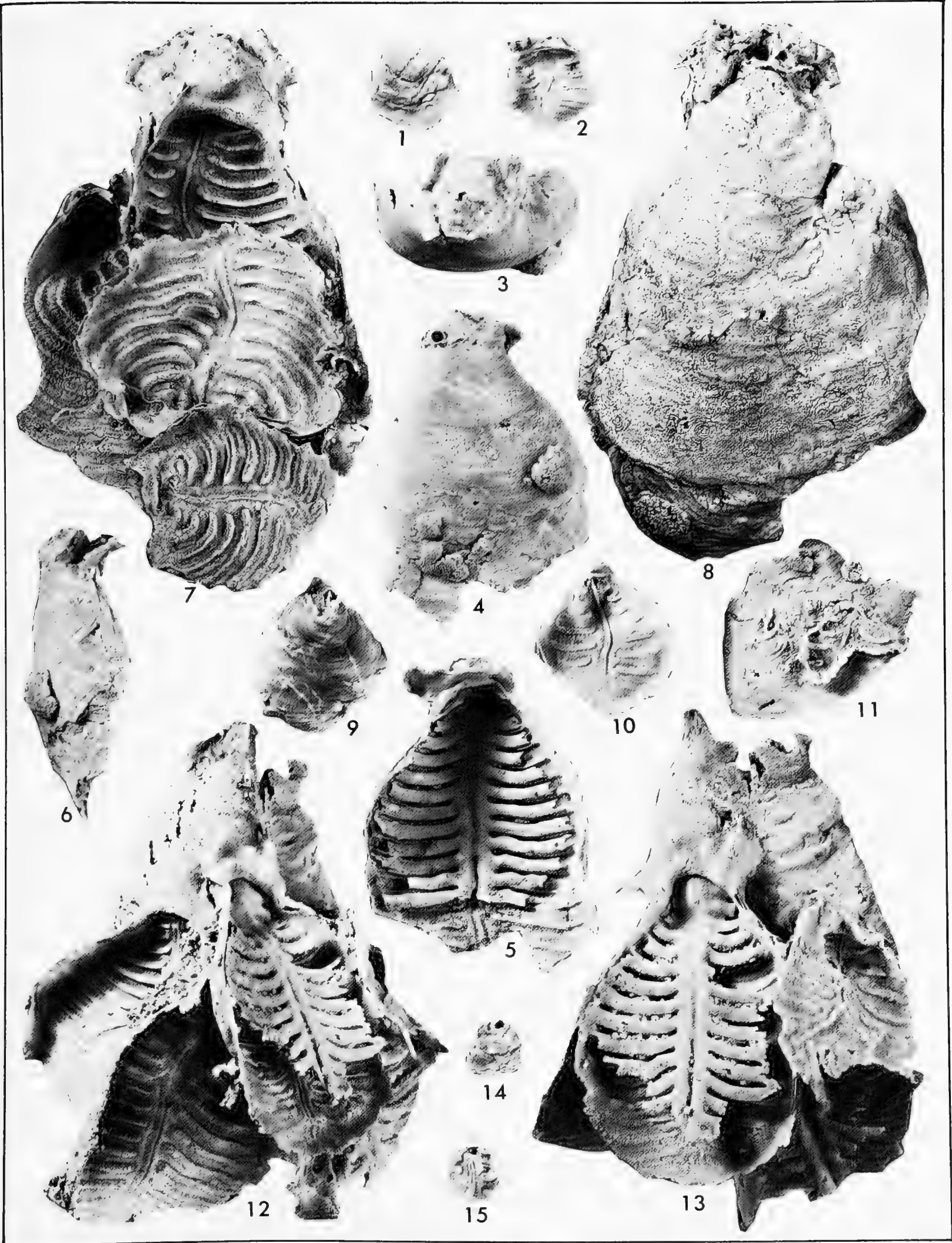
*Collemataria*

*Collemataria gregaria*, new species: 1, 2, Exterior and interior of an immature specimen with angustilobate lobes,  $\times 1$ , paratype USNM 150806d; 12, 13, two views of a cluster of specimens,  $\times 1$ , paratype USNM 150806e [Cathedral Mountain Formation, locality USNM 702 (low)].

3-6, Posterior, showing cicatrix, exterior, dorsal, and side views of a medium-sized complete specimen,  $\times 1$ , holotype USNM 150802f; 7, 8, interior and exterior of a large specimen, the inside of which is covered by attached young ones in stages of septal development varying from angustilobate to solidiseptate,  $\times 1$ , paratype USNM 153577a; 9, 10, exterior and interior of a young individual with lobes varying from latilobate to angustilobate,  $\times 1$ , paratype USNM 150802-1; 11, fragment of a pedicle valve with two young ones,  $\times 1$ , paratype USNM 153577b; 14, 15, exterior and interior of an immature specimen with angustilobation,  $\times 1$ , paratype USNM 150802j [Cathedral Mountain Formation, locality USNM 702a].



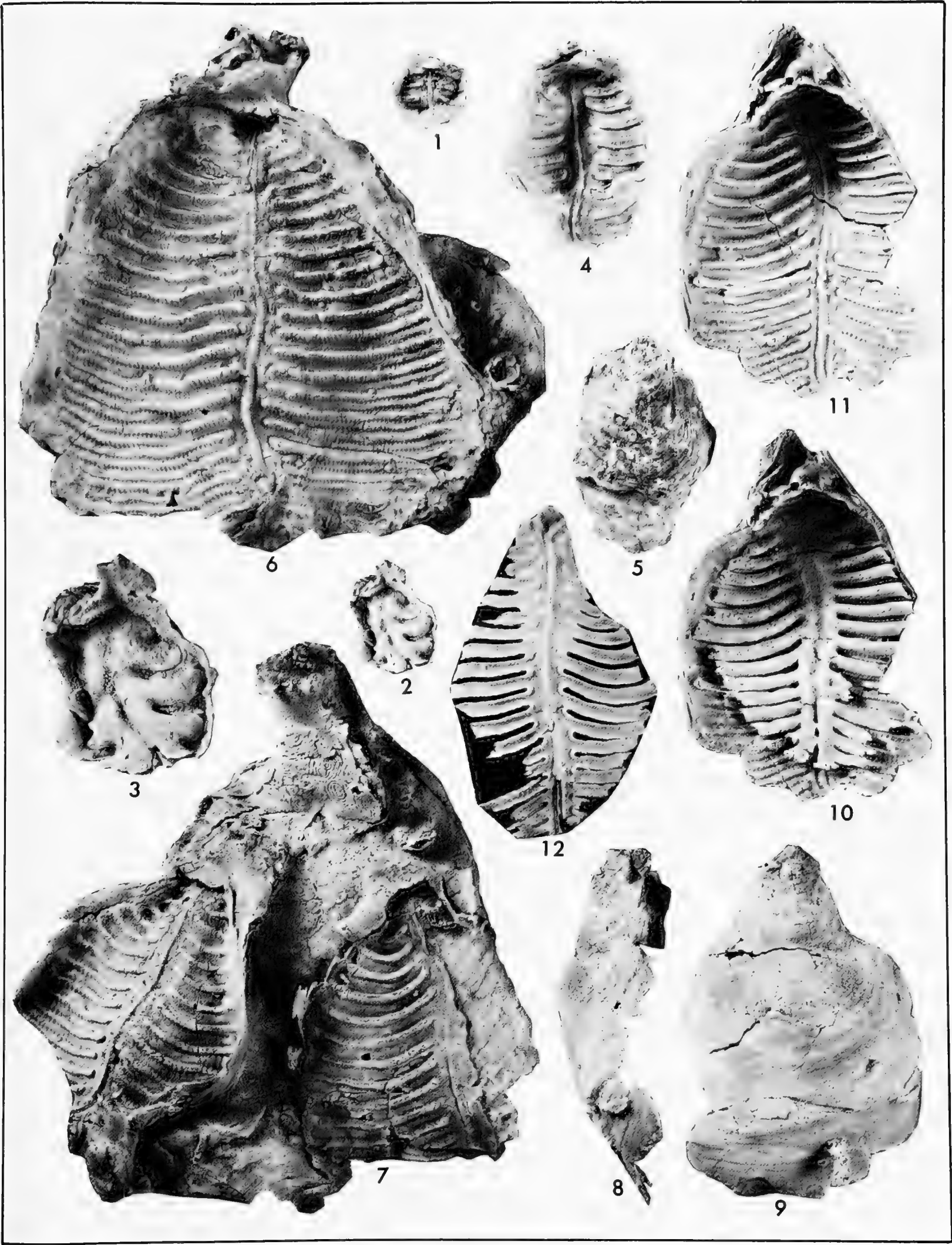
PLATE 174.—*Collemataria*.



**PLATE 175***Collemataria*

*Collemataria gregaria*, new species: 1, Interior view of an immature pedicle valve,  $\times 1$ , paratype USNM 153573c; 2, 3, immature specimen preserving both valves,  $\times 1$ ,  $\times 2$ , paratype USNM 153573a; 4, 5, interior and exterior views of a small pedicle valve,  $\times 1$ , paratype USNM 150802k; 6, 7, interior and exterior of a large, expanding specimen with two others attached,  $\times 1$ , paratype 150802a (note different lobe development with size); 8-10, side, exterior, and dorsal views of a complete specimen,  $\times 1$ , paratype 150800h; 11, interior of the pedicle valve with a majority of solidisepta of the preceding specimen,  $\times 1$ ; 12, interior of the brachial valve of the preceding specimen,  $\times 1$  [Cathedral Mountain Formation, locality USNM 702].

PLATE 175.—*Collemataria*.



## PLATE 176

*Collemataria*

*Collemataria gregaria*, new species; 1, 2, Exterior and interior of an immature specimen,  $\times 1$ , paratype USNM 153373b; 3, 4, dorsal and exterior views of an immature individual with both valves,  $\times 1$ , paratype USNM 153573d [Cathedral Mountain Formation, locality USNM 702].

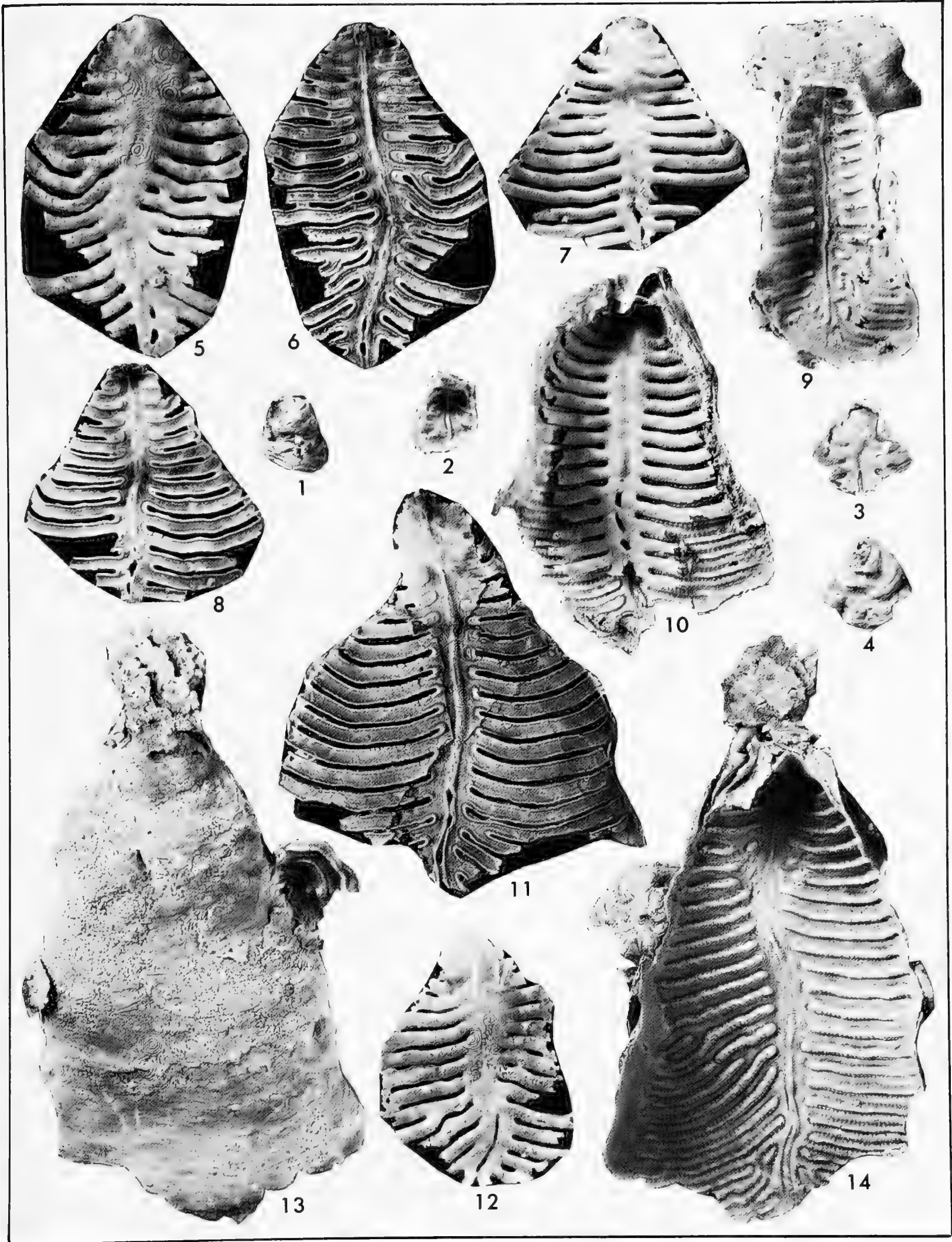
5, 6, Exterior and interior of a large brachial valve, showing cardinal process and row of holes at anterior end of axial groove,  $\times 1$ , paratype USNM 153574a; 7, 8, another brachial valve, exterior and interior views,  $\times 1$ , paratype USNM 153574b; 11, interior of a large and expanded brachial valve,  $\times 1$ , paratype USNM 150801a; 12, exterior of a small brachial valve,  $\times 1$ , paratype USNM 150801b, showing branching lobes; 13, 14, exterior and interior of a large solidiseptate pedicle valve,  $\times 1$ , paratype USNM 150802b [Cathedral Mountain Formation, locality USNM 702a].

9, Interior of the pedicle valve of an elongate solidiseptate specimen, showing callus wash of attachment at the posterior,  $\times 1$ , paratype USNM 153576 [Cathedral Mountain Formation, locality USNM 703a].

10, Dorsal view of a complete specimen, showing brachial valve in place and a row of pores at the anterior end of the axis,  $\times 1$ , paratype USNM 150806a [Cathedral Mountain Formation, locality USNM 702 (low)].



PLATE 176.—*Collemataria*.



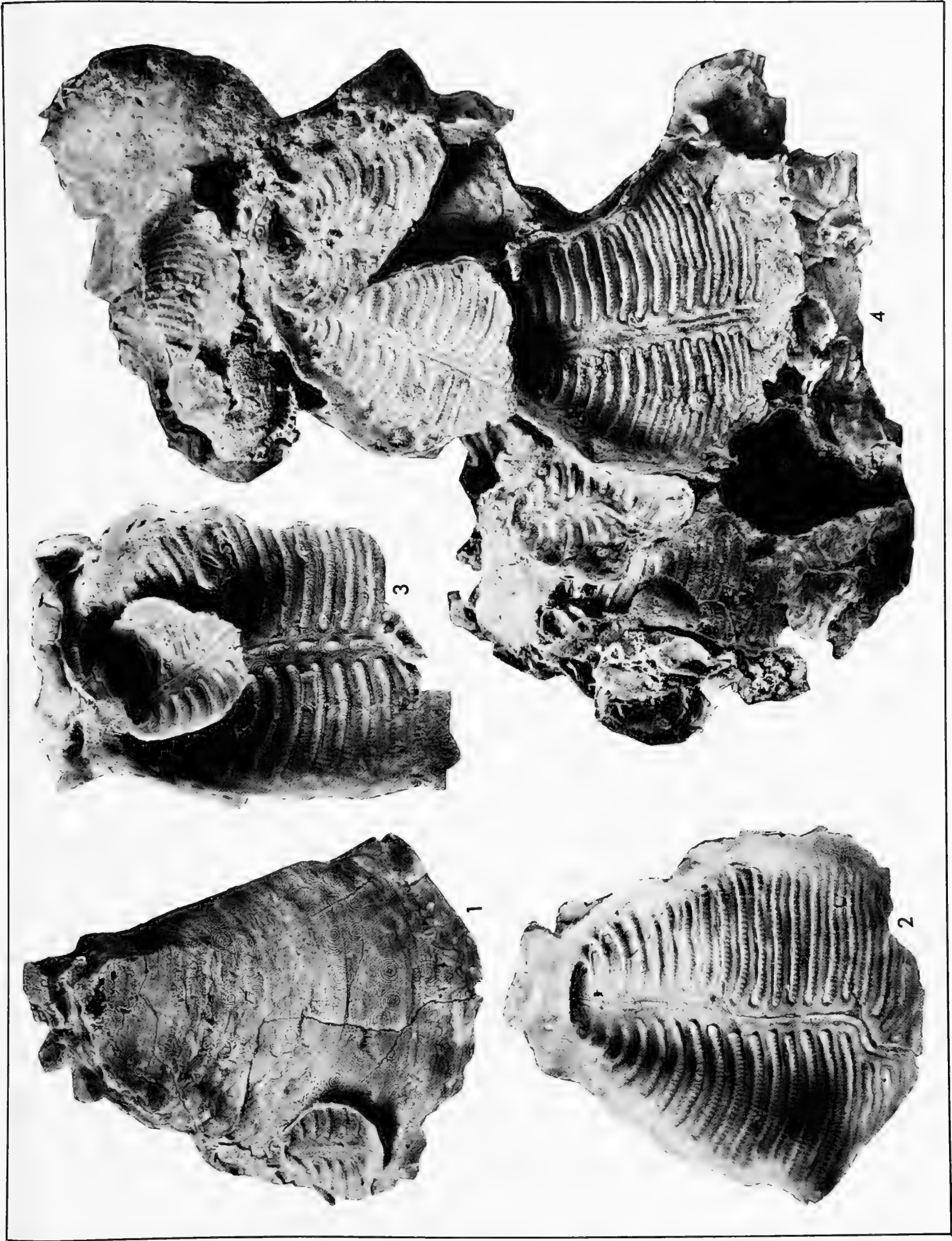


**PLATE 177***Collemataria*

*Collemataria gregaria*, new species: 1, 2, Exterior and interior of a large pedicle solidiseptate valve,  $\times$  1, paratype USNM 150802c [Cathedral Mountain Formation, locality USNM 702a<sup>1</sup>].

3, Interior of another pedicle valve (solidiseptate) with small one (angustilobate) attached,  $\times$  1, paratype USNM 150800a; 4, dorsal view of a large cluster,  $\times$  1, paratype USNM 153575 [Cathedral Mountain Formation, locality USNM 702].

PLATE 177.—*Collemataria*.



## PLATE 178

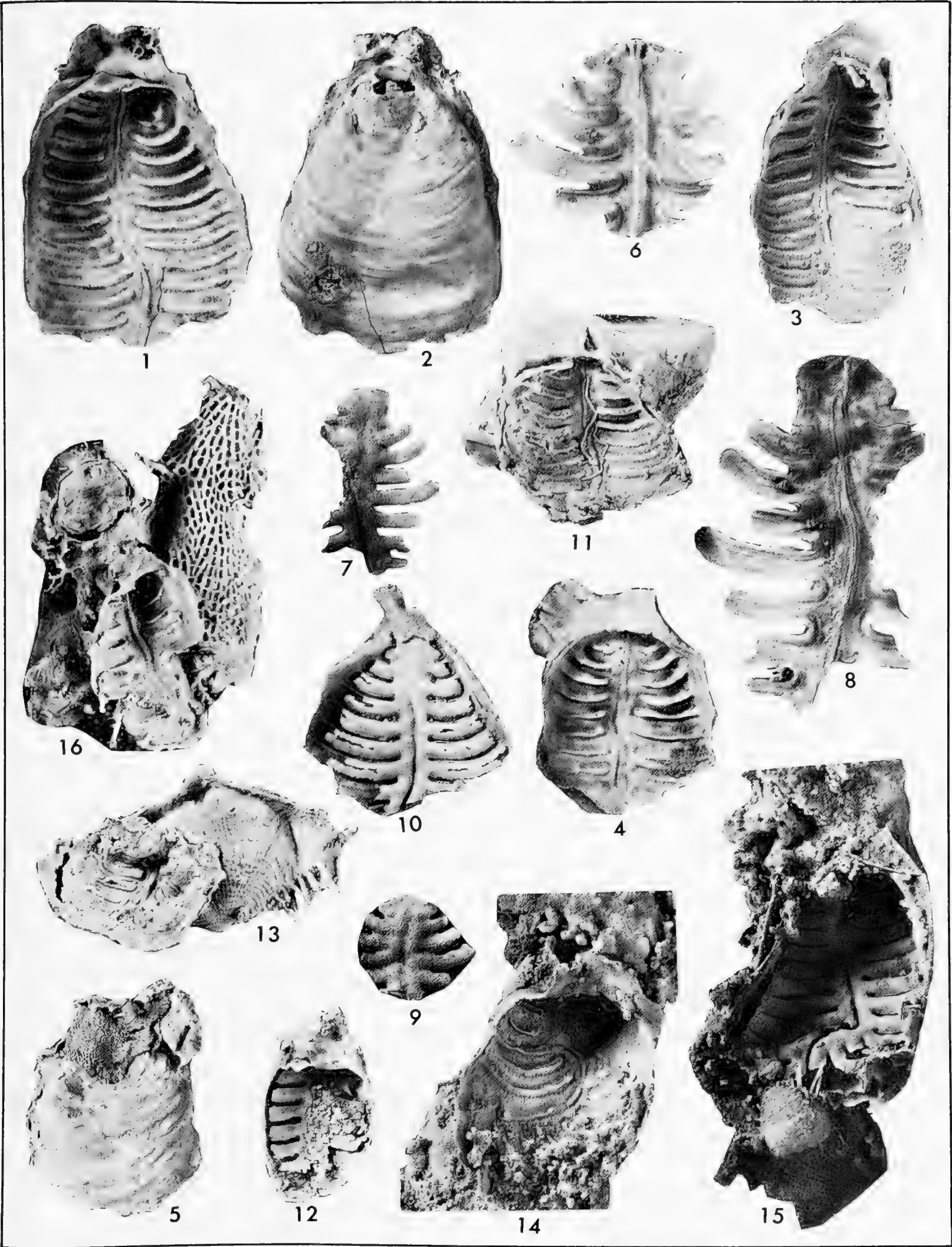
*Collemataria*

*Collemataria, irregularis*, new species: 1, 2, Interior and exterior views of a large solidiseptate to anguliseptate pedicle valve, with slight cowl and posterior flap,  $\times 1$ , holotype USNM 153635a; 3, interior of another pedicle valve, mostly anguliseptate, narrower than the preceding,  $\times 1$ , paratype USNM 153635b; 4, 5, interior and exterior views of a small pedicle valve, angustilobate to anguliseptate,  $\times 1$ , paratype USNM 153635c; 6, posterior of a brachial valve, showing the cardinal process,  $\times 2$ , paratype USNM 153635d; 7, exterior of another brachial valve,  $\times 1$ , paratype USNM 153635e; 8, interior of the preceding specimen, showing cardinal process and axial ridge,  $\times 2$ ; 9, exterior of a small brachial valve with granulose surface,  $\times 1$ , paratype USNM 153635f; 10, dorsal view of a small, acuminate individual with brachial valve in place,  $\times 1$  [Cathedral Mountain Formation, locality USNM 721u].

11, Angustilobate pedicle valve attached to *Neospirifer*,  $\times 1$ , paratype USNM 150752f; 12, small individual with brachial valve in place,  $\times 1$ , paratype USNM 150752e; 13, angustilobate pedicle valve attached to *Institella*,  $\times 1$ , paratype USNM 150752g; 14, another pedicle valve attached to, and partly surrounded by, algae,  $\times 1$ , paratype USNM 150752b; 15, specimen with brachial valve in place, attached to algae,  $\times 1$ , paratype USNM 150752a. [Cathedral Mountain Formation (Wedin Member), locality USNM 714w].

16, Ventral view of a small pedicle valve attached to a fenestellid colony,  $\times 1$ , paratype USNM 153636 [Cathedral Mountain Formation (Wedin Member), locality USNM 723u].

PLATE 178.—*Collemataria*.



## PLATE 179

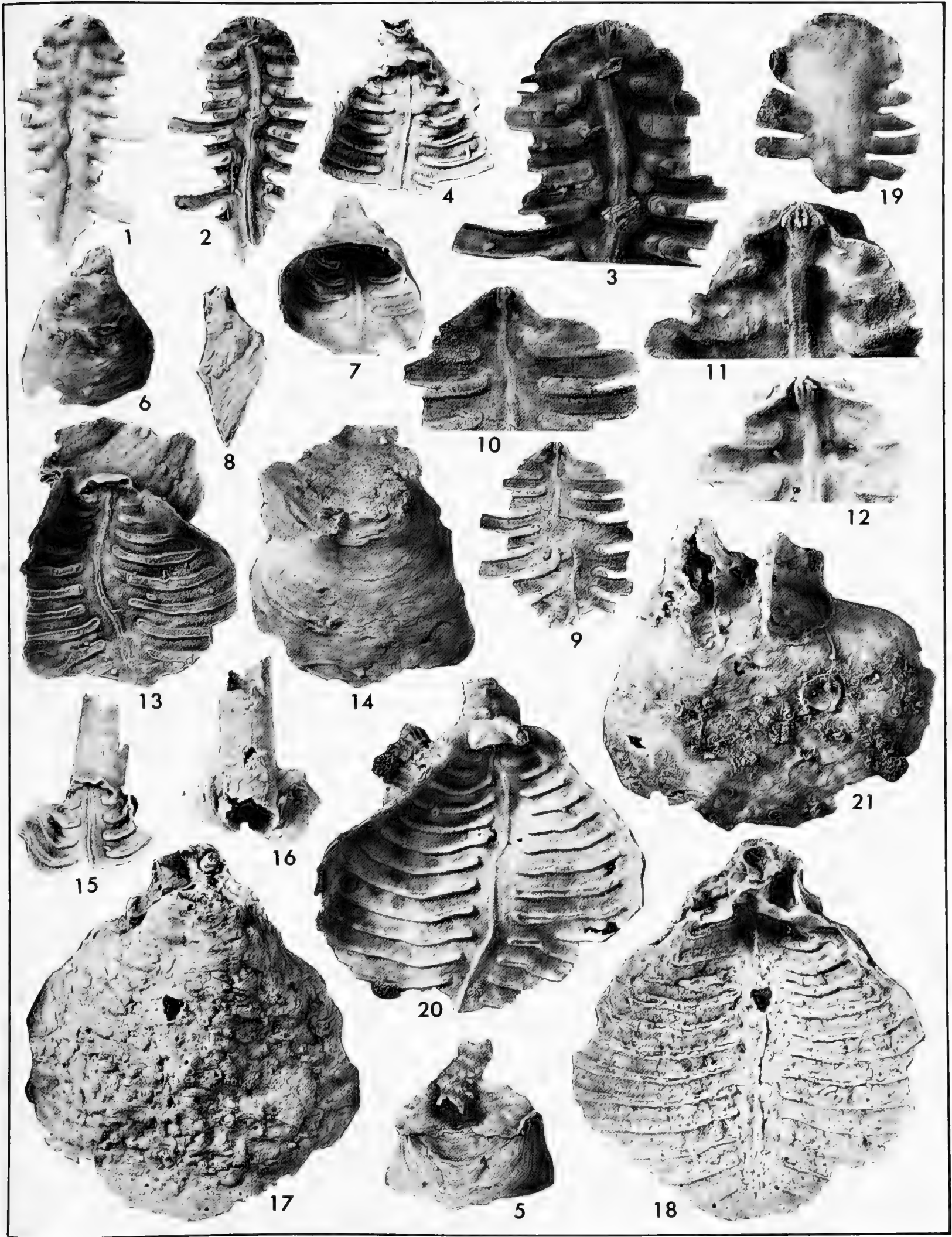
*Collemataria*

*Collemataria marshalli* (Stehli): 1, 2, Exterior and interior views of a brachial valve,  $\times 1$ , hypotype USNM 150767c; 3, interior of the preceding specimen,  $\times 2$ ; 4, 5, interior and exterior of a small pedicle angustilobate valve attached to a bryozoan,  $\times 1$ , hypotype USNM 150764; 6-8, exterior, interior, and side views of a small, acuminate pedicle valve, with angustilobate lobes,  $\times 1$ , hypotype USNM 150767d; 9, interior of another brachial valve, showing an offset in the axial ridge,  $\times 1$ , hypotype USNM 150767g; 10, posterior of the preceding specimen, showing the cardinal process,  $\times 2$ ; 11, posterior of another brachial valve, showing splayed cardinal process,  $\times 2$ , hypotype USNM 150767h; 12, posterior of a brachial valve, showing cardinal process and median ridge,  $\times 2$ , hypotype USNM 150767i; 13, 14, interior and exterior of a pedicle valve with wide angustilobate lobes, with large posterior flap,  $\times 1$ , hypotype USNM 150767j; 15, 16, immature angustilobate pedicle valve attached to a crinoid stem,  $\times 1$ , hypotype USNM 150767b; 17, 18, exterior and interior views of a large angustilobate individual,  $\times 1$ , hypotype USNM 150767a [Bone Spring Formation (base), locality USNM 728e].

19, Exterior of the posterior part of a large brachial valve,  $\times 1$ , hypotype USNM 150766a; 20, 21, interior and exterior views of a pedicle valve with angustilobate lobes,  $\times 1$ , USNM 150766b [Skinner Ranch Formation (lower), locality USNM 720e].



PLATE 179.—*Collemataria*.



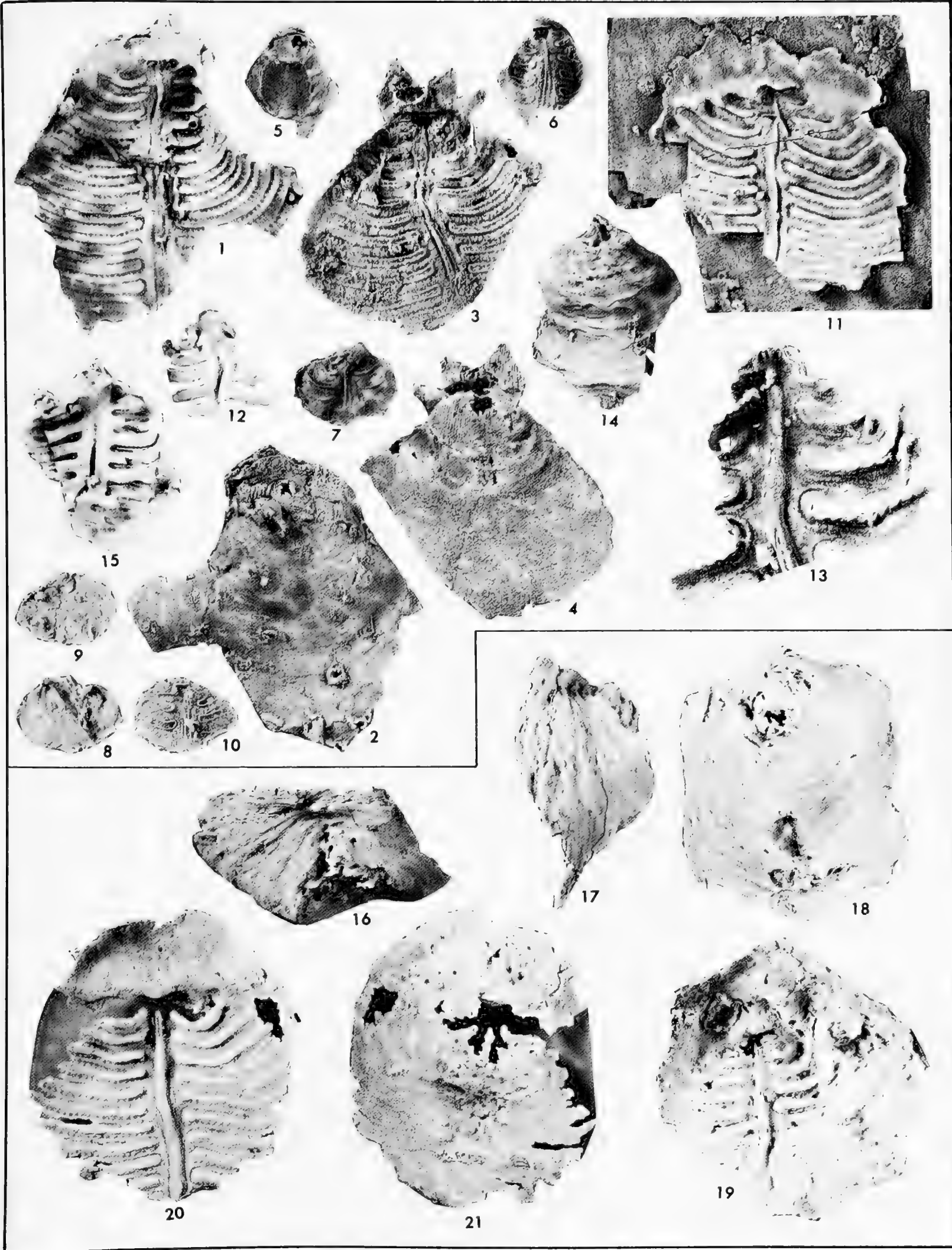
## PLATE 180

*Collemataria* and *Eolyttonia*

*Collemataria platys*, new species: 1, 2, Interior and exterior of a large solidiseptate pedicle valve,  $\times 1$ , holotype USNM 150734a; 3, 4, interior and exterior of another pedicle valve,  $\times 1$ , paratype USNM 150734c; 5, 6, exterior and interior of an immature latilobate pedicle valve,  $\times 1$ , paratype USNM 150734d; 7, 8, interior and exterior of another immature latilobate pedicle valve,  $\times 1$ , paratype USNM 150734e; 9, 10, exterior and interior of flat, immature pedicle valve with latilobate lobes,  $\times 1$ , paratype USNM 150734f; 11, imperfect pedicle valve with angustilobate to solidiseptate lobes, attached to a *Pinna*-like pelecypod shell,  $\times 1$ , paratype USNM 150734b; 12, exterior of an imperfect brachial valve,  $\times 1$ , paratype USNM 150734g; 13, interior view of the same specimen as preceding, showing small cardinal process,  $\times 2$ ; 14, 15, ventral and dorsal views of a fragmentary specimen, preserving part of the brachial valve,  $\times 1$ , paratype USNM 150734h [Skinner Ranch Formation (base), locality USNM 705a].

*Eolyttonia phialiforma*, new species: 16–19, Posterior, side, ventral, and interior views of a pedicle valve with large cowl, and solidisepta, holotype,  $\times 1$ , USNM 150666a; 20, 21, interior and exterior of another pedicle valve, shallower than the preceding but with a large cowl,  $\times 1$ , paratype USNM 150666b [Neal Ranch Formation (top of bed 2=Gray Limestone of P. B. King), locality USNM 722x].

PLATE 180.—*Collemataria* and *Eolyttonia*.



## PLATE 181

*Collemataria*

*Collemataria spatulata*, new species: 1-3, Ventral, side, and dorsal views of a long septivallate pedicle valve,  $\times$  1, paratype USNM 150757a; 4-7, side, ventral, dorsal, and posterior views of another specimen, preserving part of the brachial valve,  $\times$  1, holotype USNM 150757b; 10, interior of an incomplete brachial valve, showing cardinal process,  $\times$  2, paratype USNM 150757c [Bell Canyon Formation (Lamar Member), locality USNM 738b].

8, 9, 11, Ventral, posterior, and interior views of a long septivallate pedicle valve,  $\times$  1, paratype USNM 152628 [Bell Canyon Formation (Lamar Member), locality USNM 725e].

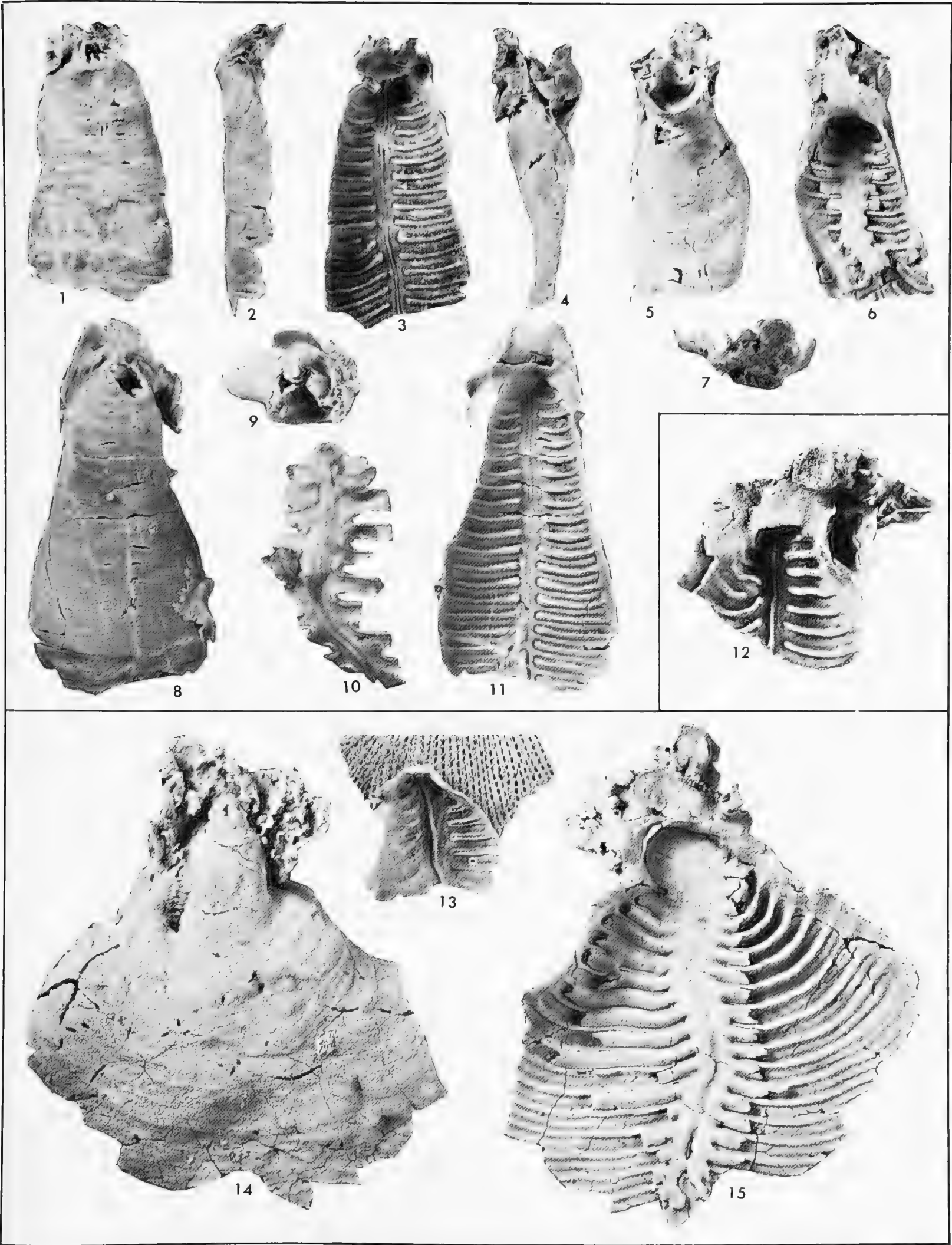
*Collemataria americana* (Girty): 12, Interior of the lectotype, solidiseptate lobes,  $\times$  1, USNM 118513 [Bone Spring Formation, locality USGS 3764 (green) ].

*Collemataria elongata*, new species: 13, Small pedicle valve with angustilobate lobes attached to a fenestellid frond,  $\times$  1, paratype USNM 153629 [Word Formation (Willis Ranch Member), locality USNM 706e].

14, 15, Exterior and interior of a large, expanding individual with brachial valve in place and with solidiseptate lobes,  $\times$  1, paratype USNM 150819a [Word Formation (China Tank Member), locality USNM 706c].



PLATE 181.—*Collemataria*.





## PLATE 182

*Rigbyella* and *Coscinophora*

*Rigbyella girtyi* (Wanner and Sieverts): 1, 2, Dorsal and ventral views of a complete specimen,  $\times 1$ , holotype USNM 118512; 3, 4, same views,  $\times 4$  [Capitan Formation, locality USGS 2906 (green)].

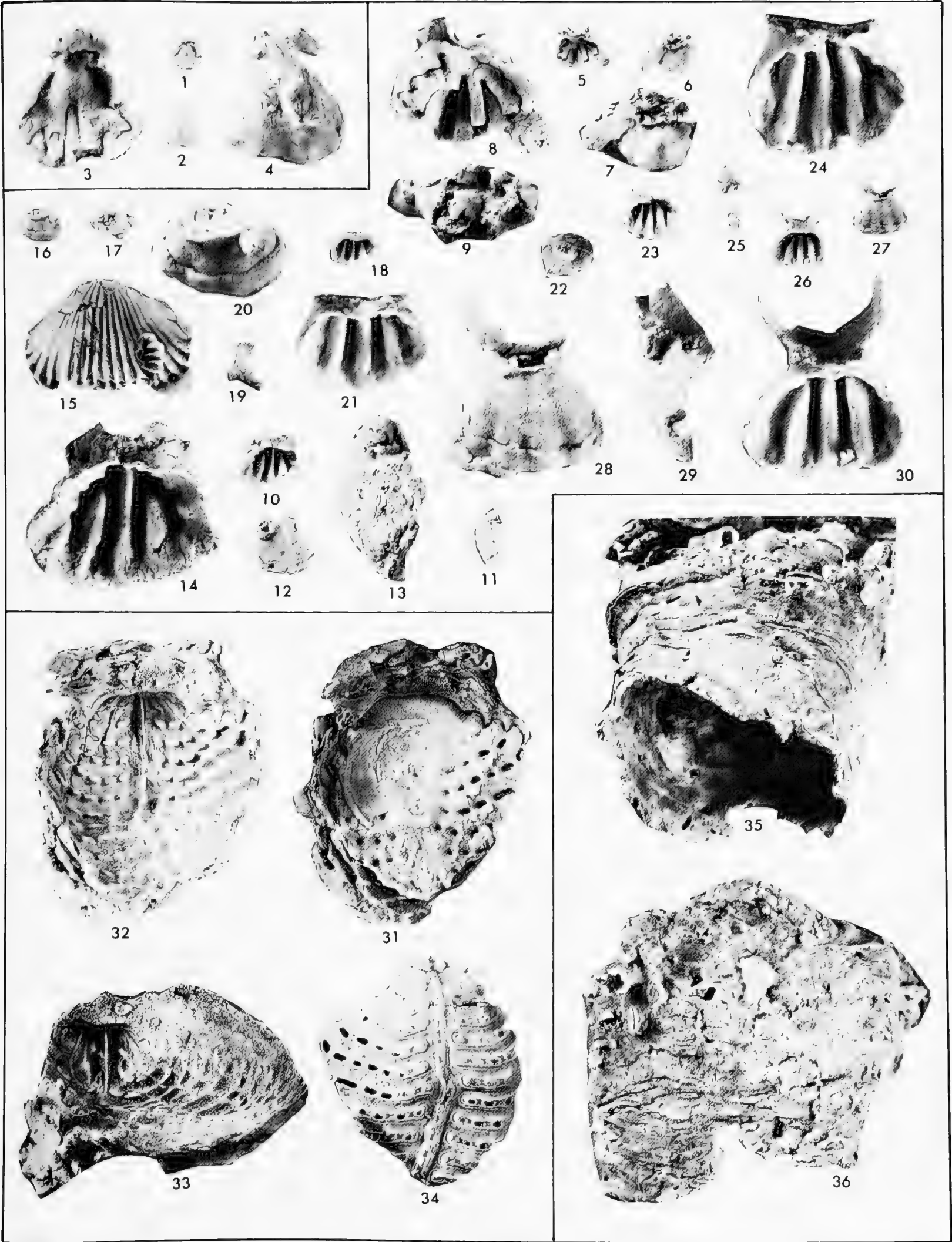
5, 6, Dorsal and ventral views of a complete specimen,  $\times 1$ , hypotype AMNH 27933:2; 7, ventral view of the preceding specimen,  $\times 2$ ; 8, 9, dorsal and posterior views of the preceding specimen,  $\times 3$ ; 10–12, interior, side, and ventral views of a pedicle valve, showing solidiseptate lobes,  $\times 1$ , hypotype AMNH 27933:1; 13, 14, side and interior views of the preceding specimen,  $\times 3$ ; 15, pedicle valve attached to the brachial valve of *Stenosisma*,  $\times 1$ , hypotype AMNH 27933:3 [Bell Canyon Formation (Lamar Member), locality AMNH 38].

16–19, Ventral, posterior, interior, and side views of a pedicle valve,  $\times 1$ , hypotype USNM 147719c; 20, 21, ventral and interior views of the preceding solidiseptate specimen,  $\times 3$ ; 22, 23, ventral and interior views of another pedicle valve,  $\times 1$ , hypotype USNM 147719a; 24, interior of the preceding specimen, showing the direct lobes,  $\times 3$ ; 25–27, side, interior, and ventral views of another pedicle valve, retaining parts of the host,  $\times 1$ , hypotype USNM 147719b; 28–30, ventral, side, and interior views of the preceding specimen,  $\times 3$  [Bell Canyon Formation (Lamar Member), locality USNM 738b].

*Coscinophora nodosa* Cooper and Stehli: 31, Dorsal view of an individual with both valves,  $\times 1$ , holotype USNM 124121b; 32, interior of the pedicle valve of the holotype, showing muscle scars and median septum,  $\times 1$ ; 33, the same holotype interior, tilted to show the median septum and diductor scars,  $\times 1$ ; 34, interior of the brachial valve of the holotype,  $\times 1$ , [Cathedral Mountain Formation, locality AMNH, 500H=USNM 702].

*Coscinophora magnifica*, new species: 35, 36, Dorsal and side views of an unusually conical pedicle valve formed by exceptionally long cowl,  $\times 1$ , paratype USNM 153655c [Road Canyon Formation, locality USNM 721j].

PLATE 182.—*Rigbyella* and *Coscinophora*.



## PLATE 183

*Coscinophora*, *Pseudoleptodus*, *Choanodus*, *Paranorella*, and *Collemataria*

*Coscinophora monilifera*, new species: 1, Specimen showing the sievelike brachial valve in place,  $\times 1$ , paratype USNM 153564 [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].

*Pseudoleptodus grandis*, new species: 2-4, Side, exterior, and interior views of a large pedicle valve with angustilobate lobes, with another smaller specimen attached,  $\times 1$ , holotype USNM 153567a; 5, interior view of the holotype enlarged,  $\times 2$ ; 6, posterior hinge region of the holotype, showing deep muscle scar bounded by ridges,  $\times 3$ ; 7, 8, interior and exterior of a brachial valve,  $\times 1$ , paratype USNM 153567b; 9, interior of the brachial valve, showing the remnantal cardinal process,  $\times 2$ ; 10, interior view of the specimen attached to the holotype, which is angustilobate,  $\times 2$ , USNM 153567c [lens between the Willis Ranch and Appel Ranch Members (above lens at USNM 706b) locality USNM 737w].

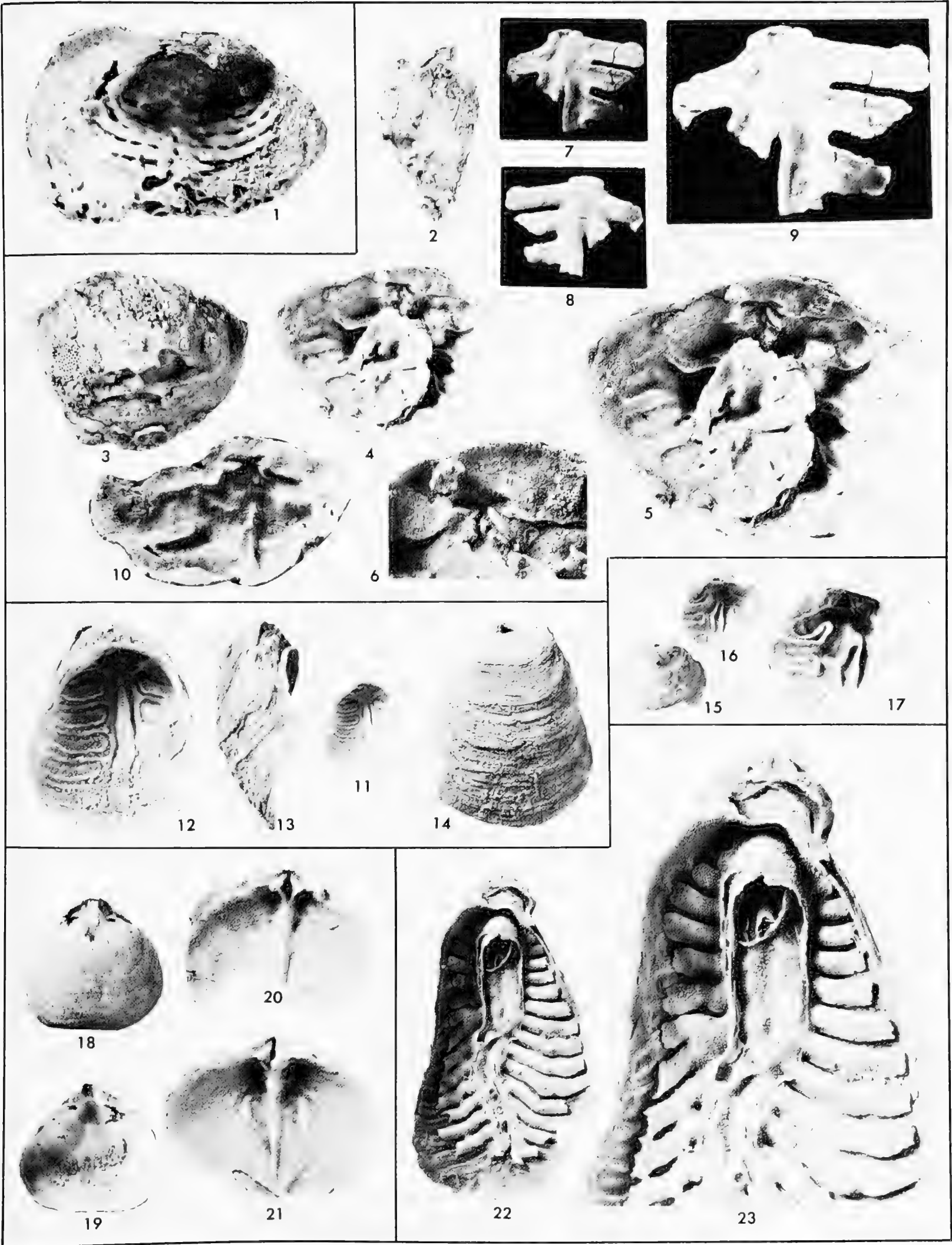
*Choanodus anomalus*, new species: 11, Interior of a young pedicle valve with thickened in-lobes,  $\times 1$ , holotype USNM 153569a; 12-14, interior, side, and exterior views of the same,  $\times 2$  [Cathedral Mountain Formation (lower), locality USNM 721u].

*Pseudoleptodus* species 8: 15, 16, 17, Exterior and interior views of a small circumvallate specimen,  $\times 1$ ,  $\times 1$ ,  $\times 2$ , figured specimen USNM 153568 [Word Formation (upper), locality USNM 737b].

*Paranorella* species: 18, 19, Exterior and interior of a pedicle valve,  $\times 1$ , figured specimen 153565a; 20, 21, interior of two fragmentary brachial valves showing cardinalia and median ridge,  $\times 2$ , figured specimens 153565b, c [Cathedral Mountain Formation, locality USNM 721u].

*Collemataria elongata*, new species: 22, Dorsal view of a specimen with the brachial valve in place,  $\times 1$ , paratype USNM 153566; 23, posterior of the preceding specimen, showing the exploded blisters at the posterior end of the brachial valve,  $\times 2$  [Word Formation (Willis Ranch Member), locality USNM 706e].

PLATE 183.—*Coscinophora*, *Pseudoleptodus*, *Choanodus*, *Paranorella*, and *Collemataria*.



## PLATE 184

*Coscinophora*

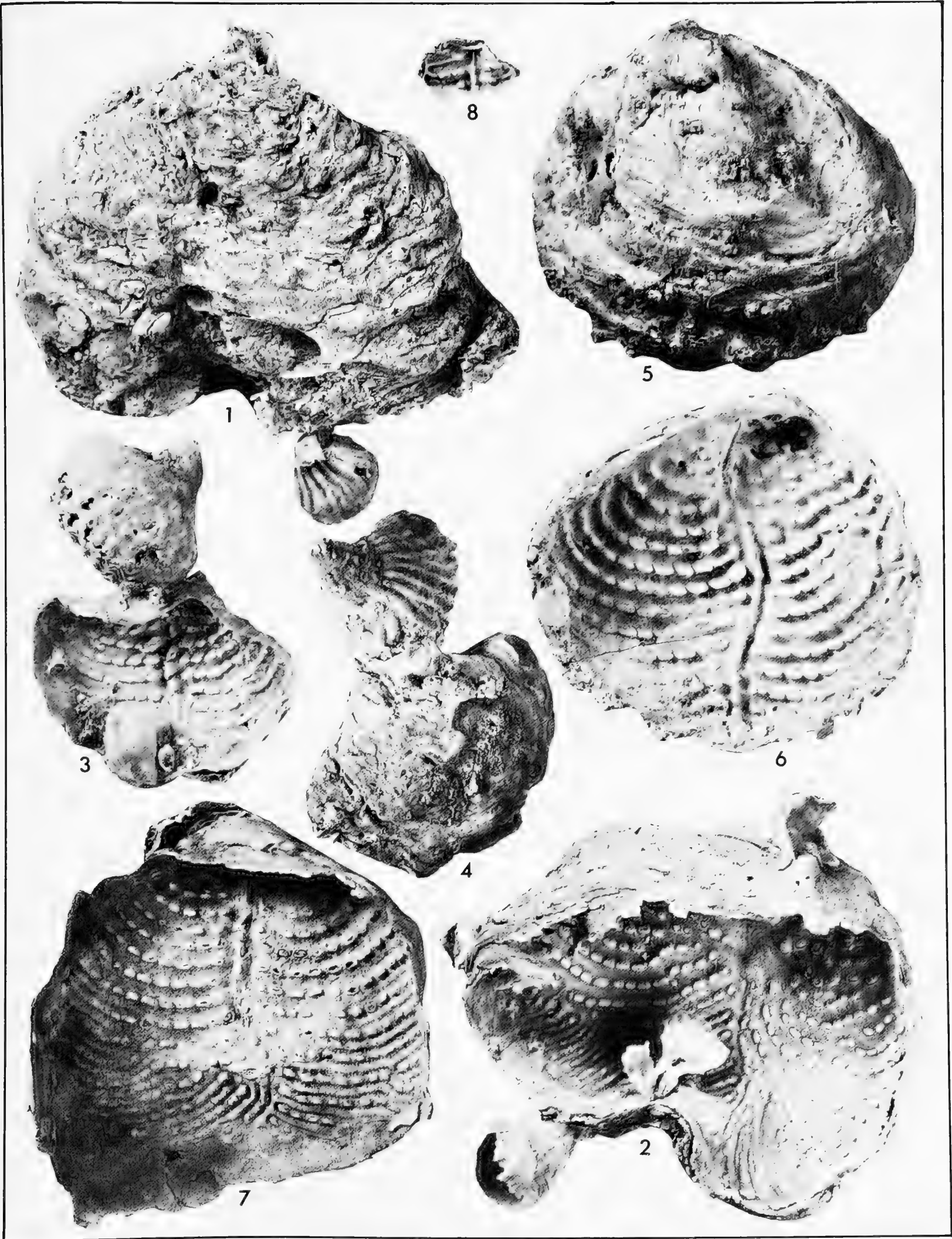
*Coscinophora magnifica*, new species: 1, 2, Ventral and dorsal views of a large pedicle valve having a large cowl and irregular development of beads,  $\times 1$ , paratype USNM 151330a; 3, 4, dorsal and ventral views of a small adult attached to *Meekella calathica*,  $\times 1$ , paratype USNM 151330b; 8, dorsal (interior) view of an immature specimen, showing lobes partially vallate and partially beaded,  $\times 1$ , paratype USNM 151330h [Road Canyon Formation, locality USNM 721j].

5, 6, Ventral and dorsal views of a medium-sized pedicle valve with well-developed rows of beads,  $\times 1$ , paratype USNM 151331a [Road Canyon Formation, locality USNM 721t].

7, Interior of a large pedicle valve with small cowl,  $\times 1$ , paratype USNM 153592c [Road Canyon Formation, locality USNM 721w].



PLATE 184.—*Coscinophora*.



## PLATE 185

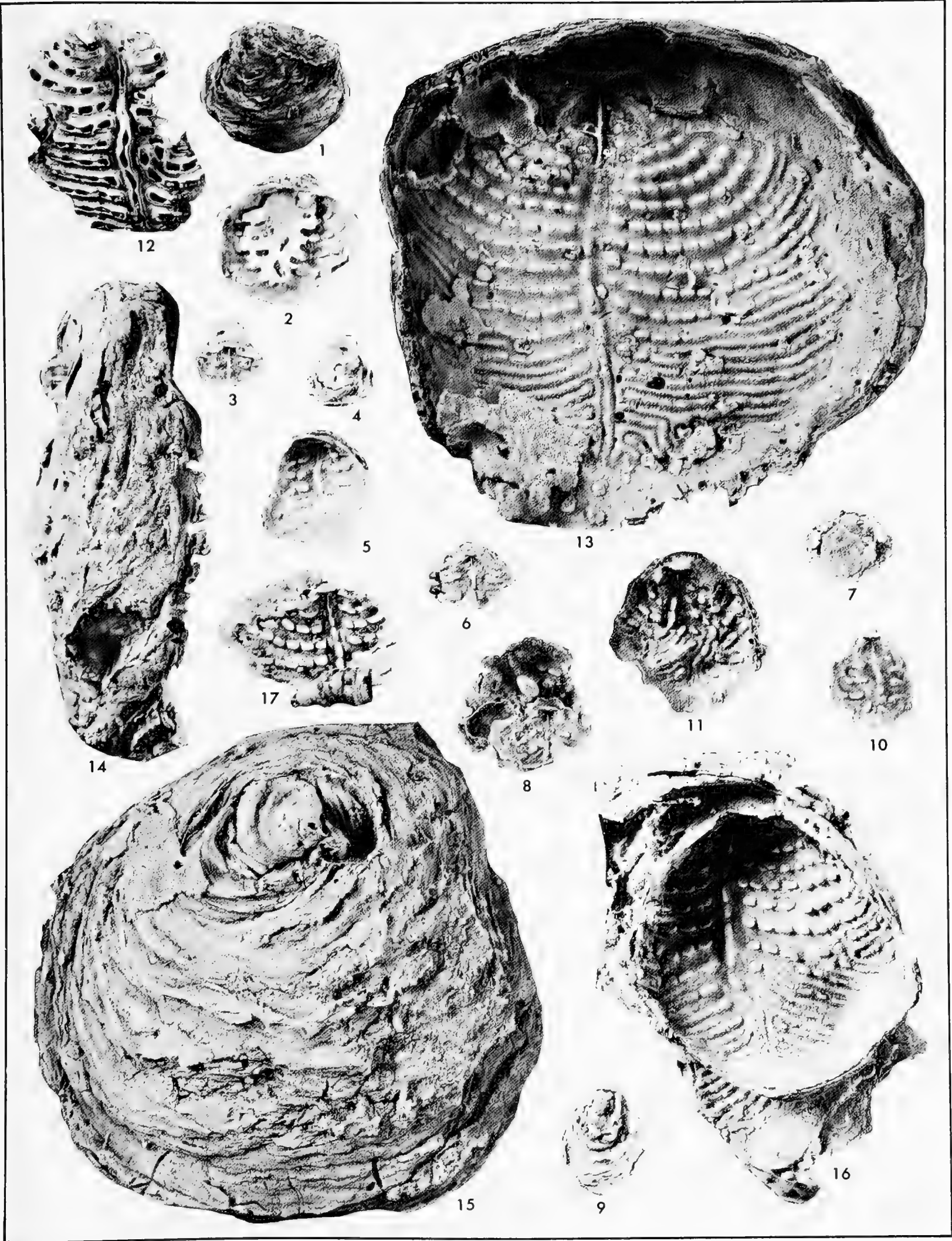
*Coscinophora*

*Coscinophora magnifica*, new species: 1, 2, Ventral and dorsal views of a young adult with the brachial valve in place,  $\times 1$ , paratype USNM 153591b; 3, 4, dorsal and ventral views of an immature specimen,  $\times 1$ , paratype USNM 153591c; 5, interior of a young, wholly fragmentivallate specimen,  $\times 1$ , paratype USNM 153591d; 6, 7, dorsal and ventral views of an immature specimen with angustilobate lobes,  $\times 1$ , paratype USNM 153591e; 8, cluster of immature fragmentivallate specimens in dorsal view,  $\times 1$ , paratype USNM 153591f; 9, 10, ventral and dorsal views of a young elongated fragmentivallate specimen,  $\times 1$ , paratype USNM 153591g; 17, interior of another young individual, showing center bead row and irregular development of side rows,  $\times 1$ , paratype USNM 154924a [Road Canyon Formation, locality USNM 709c].

11, Interior (dorsal) view of a small adult with irregular lobe development,  $\times 1$ , paratype USNM 151331f; 12, interior view of a brachial valve, showing openings in axis,  $\times 1$ , paratype USNM 151331e, [Road Canyon Formation, locality USNM 721t].

13–15, Dorsal, side, and ventral views of an unusually large and symmetrical specimen, showing reduction of beads anteriorly and insertion of parallel ridges between bead rows,  $\times 1$ , paratype USNM 150859; 16, dorsal view of a small adult with large cowl,  $\times 1$ , paratype USNM 150858c [Road Canyon Formation, locality USNM 710u].

PLATE 185.—*Coscinophora*.



## PLATE 186

*Coscinophora*

*Coscinophora magnifica*, new species: 1, 2, Brachial valve interior, showing the dendritic adductor muscle scars,  $\times 2$ ,  $\times 1$ , paratype USNM 151330i; 3, interior of a small brachial valve,  $\times 1$ , paratype USNM 151330j; 4, 5, dorsal view of a small complete specimen,  $\times 1$ ,  $\times 2$ , paratype USNM 151330k [Road Canyon Formation, locality USNM 721j].

6, Fragment of a brachial valve, showing the solid posterior of an adult without pores,  $\times 1$ , paratype USNM 153593c; 7, interior of a brachial valve, showing the adductor muscle scars,  $\times 2$ , paratype USNM 153593e; 8, interior of a small brachial valve,  $\times 1$ , paratype USNM 153593d [Road Canyon Formation, locality USNM 726d].

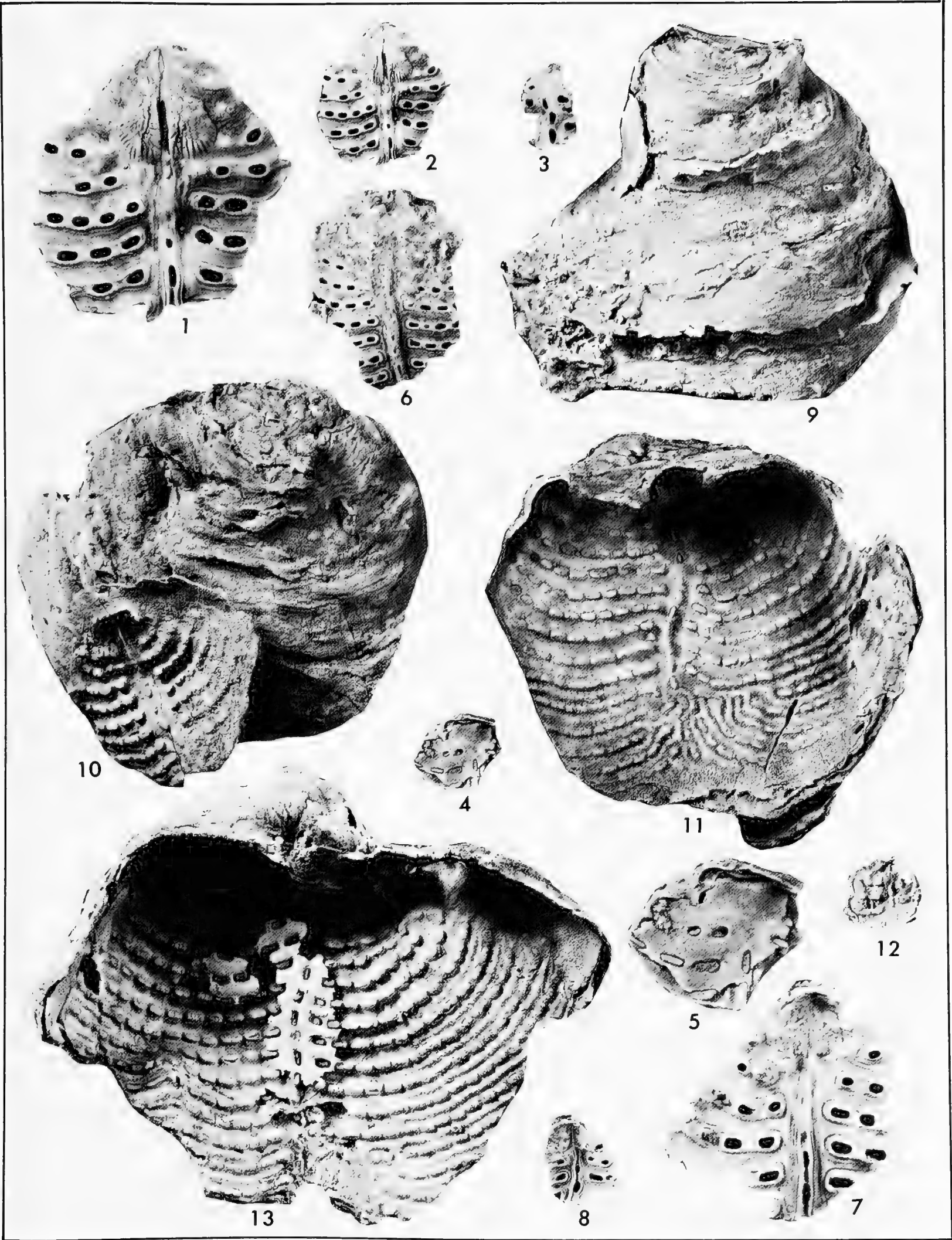
9, Exterior of a large, deformed pedicle valve,  $\times 1$ , paratype USNM 153594 [Road Canyon Formation, locality USNM 724a].

10, 11, Ventral and dorsal views of a large pedicle valve, showing irregularity in rows of beads at anterior,  $\times 1$ , paratype USNM 150856a; 12, interior of a very young individual with only three rows of beads and distal part of lobes vallate,  $\times 1$ , paratype USNM 154924b [Road Canyon Formation, locality USNM 709c].

13, Interior of a very large pedicle valve with small cowl and inserted parallel ridges anteriorly,  $\times 1$ , paratype USNM 153592b [Road Canyon Formation, locality USNM 721w].



PLATE 186.—*Coscinophora*.





## PLATE 187

*Coscinophora*

*Coscinophora magnifica*, new species: 1, Interior of a small fragmentivallate pedicle valve, showing early beginning of beaded structure,  $\times$  1, paratype USNM 153593a; 2, fragmentary brachial valve of a young individual, showing confined muscle area,  $\times$  1, paratype USNM 153593b [Road Canyon Formation, locality USNM 726d].

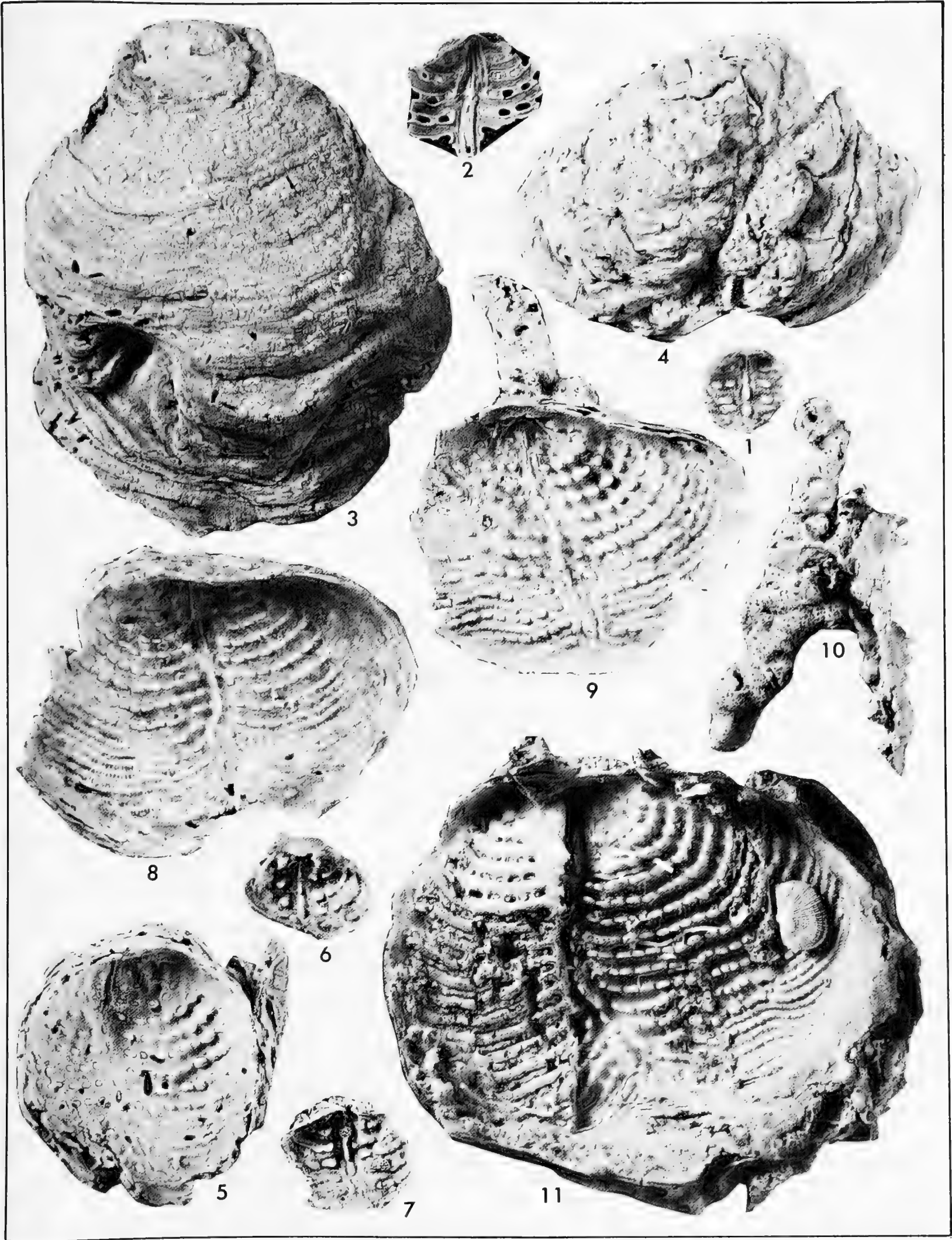
3, Exterior of a large, elongated specimen,  $\times$  1, paratype USNM 150858b [Road Canyon Formation, locality USNM 710u].

4, Exterior of two specimens of a cluster,  $\times$  1, paratype USNM 153591a; 5, interior of the specimen on the left in the preceding illustration, showing irregular lobar development,  $\times$  1; 6, 7, interior of two immature fragmentivallate specimens,  $\times$  1, paratype USNM 154924c, d [Road Canyon Formation, locality USNM 709c].

8, Interior of an imperfect specimen with short cowl,  $\times$  1, paratype USNM 151331b; 11, interior of a large specimen with part of the brachial valve attached,  $\times$  1, paratype USNM 151331c [Road Canyon Formation, locality USNM 721t].

9, 10, Interior and side views of a specimen attached to *Fissispongia*,  $\times$  1, paratype USNM 153592a [Road Canyon Formation, locality USNM 721w].

PLATE 187.—*Coscinophora*.



## PLATE 188

*Coscinophora* and *Pseudoleptodus*

*Coscinophora monilifera*, new species: 1–3, Dorsal (interior), ventral and side views of a small, symmetrical fragmentivallate specimen,  $\times 1$ , paratype USNM 153595 [Skinner Ranch Formation (Decie Ranch Member), locality USNM 707a].

*Pseudoleptodus guadalupensis* Stehli: 4, 5, Exterior and interior of a wide, incompletely circumvallate specimen with broad attachment,  $\times 1$ , hypotype USNM 154524a; 6–10, interior, exterior, interior tilted and side views,  $\times 1$ , and interior of a narrow pedicle valve preserving a long cowl and showing latilobate lobes,  $\times 2$ , hypotype USNM 154524b; 11, 12, interior and exterior of a small pedicle valve,  $\times 1$ , hypotype USNM 154524c; 13, 14, exterior,  $\times 1$ , and interior,  $\times 2$ , of a spat, showing oblique muscle scar but no vallum yet developed, hypotype USNM 154524d [Bell Canyon Formation (Rader Member), locality USNM 740j].

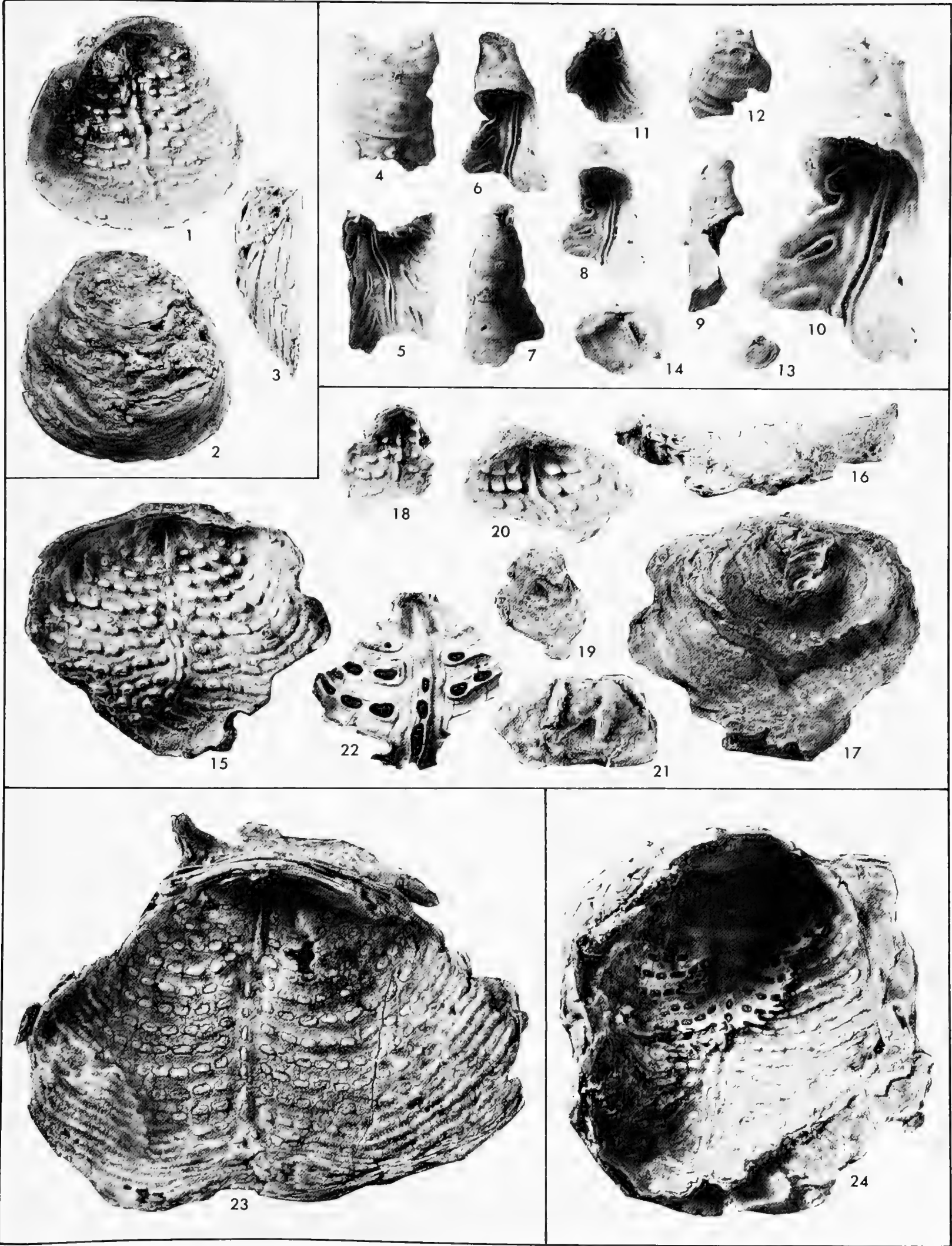
*Coscinophora magnifica*, new species: 15–17, Dorsal, posterior, and ventral (exterior) views of a small fragmentivallate adult pedicle valve with solidiseptate beads,  $\times 1$ , paratype USNM 151330e; 18, 19, interior and exterior views of a young fragmentivallate specimen with beads corresponding to solidiseptate condition,  $\times 1$ , paratype USNM 151330g; 20, 21, interior and exterior of a small pedicle valve having long and inclined beads,  $\times 1$ , paratype USNM 151330f [Road Canyon Formation, locality USNM 721j].

22, Interior of a small brachial valve, showing adductor scars,  $\times 2$ , paratype USNM 153593f [Road Canyon Formation, locality USNM 726d].

*Coscinophora monilifera*, new species: 23, Interior of a large pedicle valve, showing median septum at the posterior,  $\times 1$ , paratype USNM 153597 [Skinner Ranch Formation (Poplar Tank Member), locality USNM 707h].

*Coscinophora magnifica*, new species: 24, Dorsal view of a specimen preserving much of the brachial valve,  $\times 1$ , holotype USNM 151331d [Road Canyon Formation, locality USNM 721t].

PLATE 188.—*Coscinophora* and *Pseudoleptodus*.



## PLATE 189

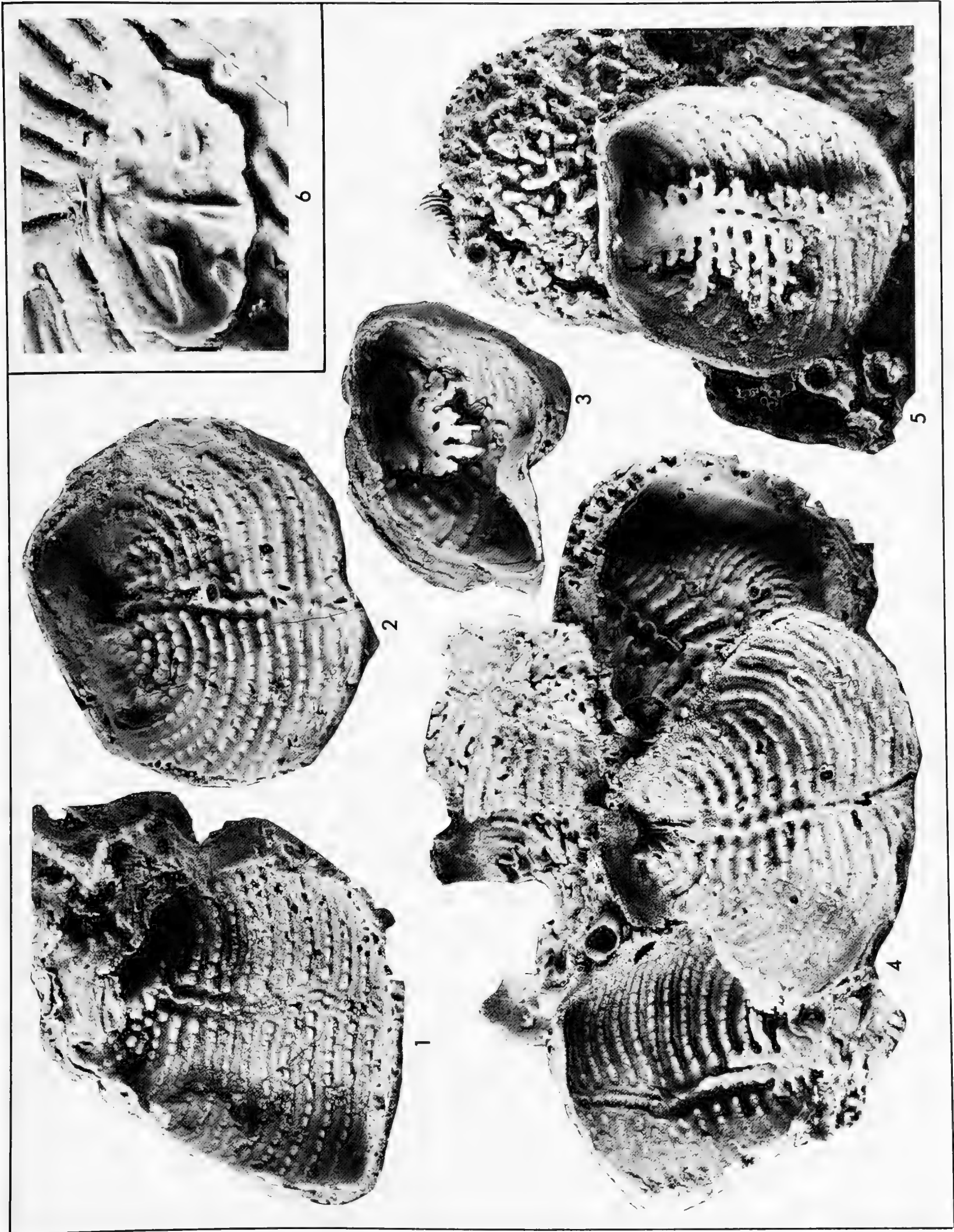
*Coscinophora* and *Pseudoleptodus*

*Coscinophora monilifera*, new species: 1, Interior of a slightly distorted pedicle valve,  $\times$  1, paratype USNM 153590e; 2, interior of another pedicle valve, tilted slightly to show short cowl,  $\times$  1, paratype USNM 153590b; 3, interior view of a small pedicle valve distorted by crowding and having a somewhat conical form,  $\times$  1, paratype USNM 153590f; 4, cluster of pedicle valves,  $\times$  1, paratype USNM 153590c; 5, small pedicle valve attached to algae(?) and associated with cup corals and showing part of the brachial valve in place,  $\times$  1, holotype USNM 153590d [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j].

*Pseudoleptodus grandis*, new species: 6, Interior of a pedicle valve attached to *Collemataria* and showing oblique muscular scar and lateral lobes passing from latilobate to angustilobate condition,  $\times$  2, paratype USNM 154525a [Word Formation (lens between Willis Ranch and Appel Ranch Members), locality USNM 742b].



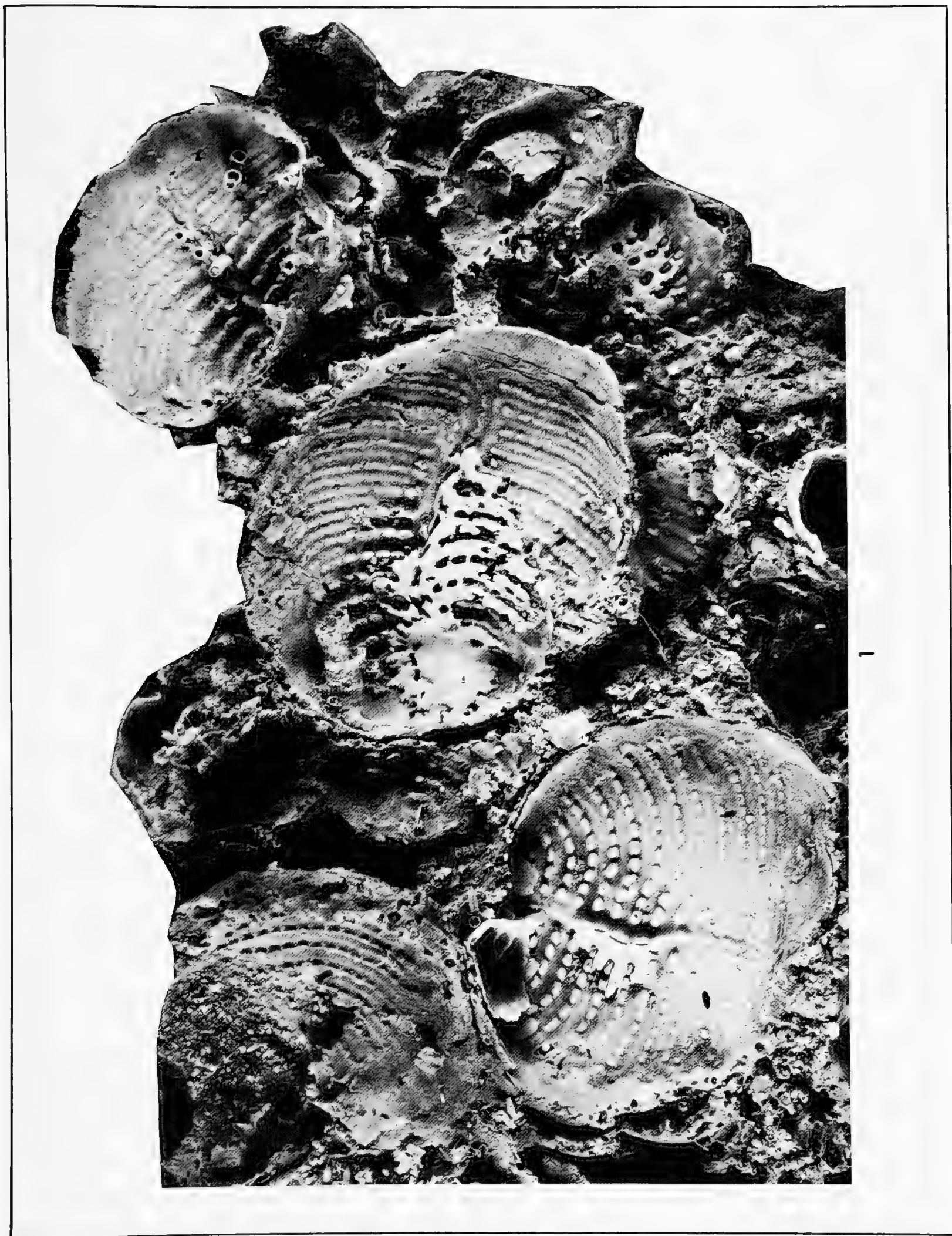
PLATE 189.—*Coscinophora* and *Pseudoleptodus*.



**PLATE 190***Coscinophora*

*Coscinophora monilifera*, new species: Part of a reefy mass of *Coscinophora* cemented with algae, sponges, and other brachiopods,  $\times 1$ , paratype USNM 153590a [Skinner Ranch Formation (Sullivan Peak Member), locality USNM 733j]. For complete mass, see Plate 129: figures 20, 21.

PLATE 190.—*Coscinophora*.



## PLATE 191

*Coscinophora*, *Eolyttonia*, *Leptodus*, *Collemataria*, and *Leptodus* (type)

*Coscinophora hortonii* (R. E. King): 1, Portion of a pedicle valve, (figured by R. E. King),  $\times 1$ , YPM 12062; 2, reverse side of the previous specimen, showing the right dental plate and a young attached specimen,  $\times 1$ ; 3, polished section of the previous specimen, showing the beads embedded in fibrous tissue [Cathedral Mountain Formation, locality R. E. King 7].

*Eolyttonia* species 3: 4-7, Side, posterior, anterior, ventral views of two attached specimens, showing a large cowl,  $\times 1$ , type USNM 150774 [Bell Canyon Formation (Lamar Member), locality, USNM 738b].

*Leptodus nobilis* Waagen: 8, Polished section of a small part of a pedicle valve, showing the lobes buried in secondary (fibrous) shell,  $\times 3$ , hypotype USNM 147731 [Permian, Salt Range, Pakistan].

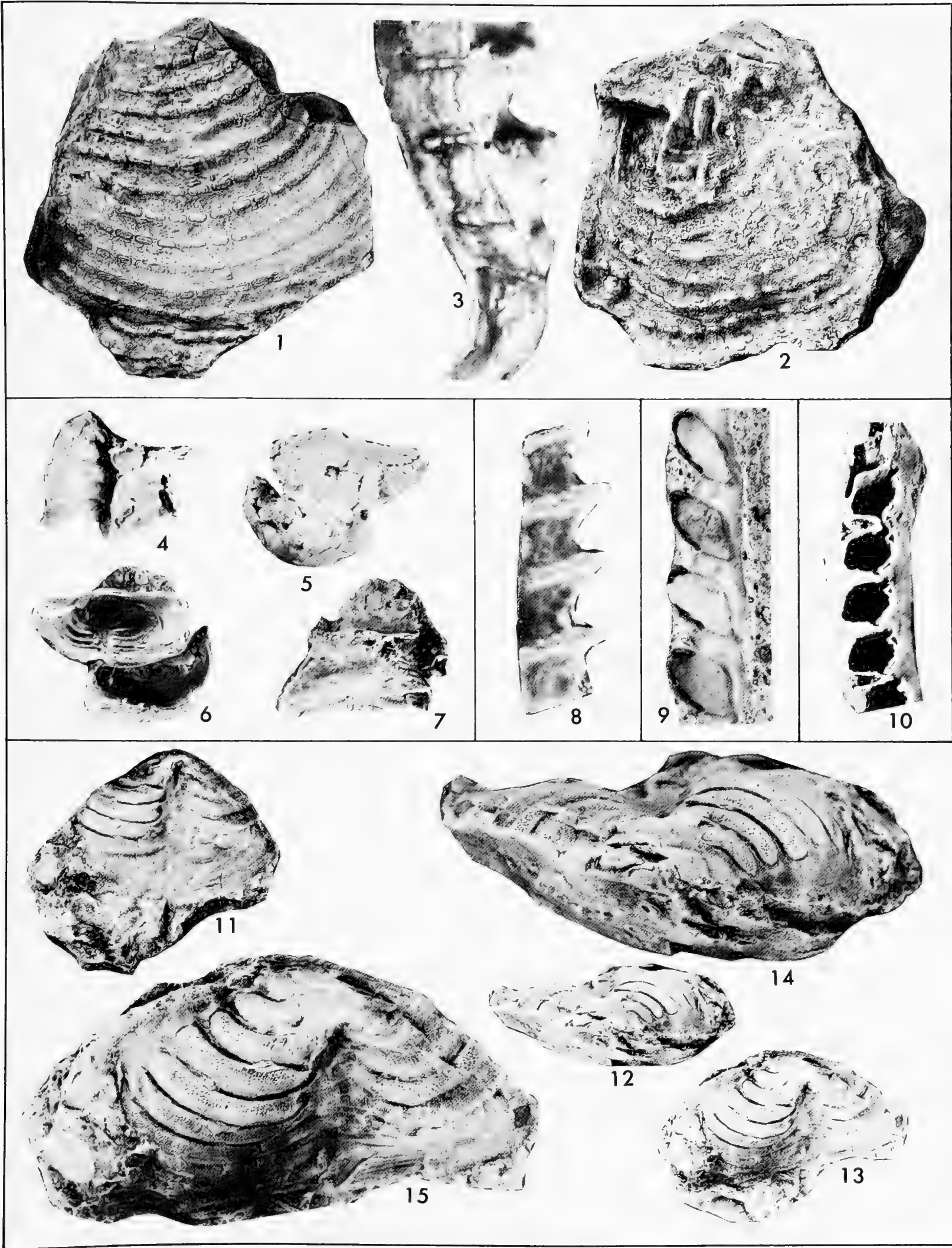
*Leptodus nobilis* Waagen: 9, Polished section, showing loops capped by brachial valve lobes,  $\times 3$ , hypotype USNM 153658 [Permian (Middle Productus Limestone), dam site north of Warcha, Salt Range, Pakistan].

*Collemataria elongata*, new species: 10, Section of a specimen, showing the ventral and dorsal lobes of the brachial valve in contact,  $\times 2$ , paratype USNM 153634i [Word Formation (Willis Ranch Member), locality USNM 706e].

*Leptodus richthofeni* Kayser: 11-13, Ventral, posterior, and tilted ventral view of the lectotype, showing the lobes,  $\times 1$ , (figured by E. Kayser, in Baron von Richthofen's *China*, plate 21: figures 11, 11a); 14, 15, posterior and ventral tilted views of the preceding specimen, showing the lobes with solidisepta but no evidence of a cowl,  $\times 2$  [Permian, Lo-Ping, China].



PLATE 191.—*Coscinophora*, *Eolyttonia*, *Leptodus*, *Collemataria*, and *Leptodus*.











## Publication in *Smithsonian Contributions to Paleobiology*

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Use the *metric system* instead of, or in addition to, the English system.

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